FRONTISPIECE.

A TREATISE OF ARTILLERY:

CONTAINING

I. General Conſtructions of Braſs and Iron GUNS uſed by Sea and Land, and their CARRIAGES.
II. General Conſtructions of MORTARS and HOWITZES, their BEDS and CARRIAGES.
III. DIMENSIONS of all CARRIAGES uſed in ARTILLERY.
IV. EXERCISE of the REGIMENT at Home, and SERVICE Abroad in a SIEGE or BATTLE.
V. Its MARCH and ENCAMPMENT, AMMUNITION, STORES, and HORSES.
VI. Laſtly, The neceſſary LABORATORY WORK for FIRE-SHIPS, &c.

To which is prefixed,

An INTRODUCTION,

WITH

A THEORY of POWDER applied to FIRE-ARMS.

The SECOND EDITION,
With large Additions, Alterations, and Corrections.

By JOHN MULLER,
Profeſſor of ARTILLERY and FORTIFICATION,
And Preceptor of Engineering, &c. to his Royal Highneſs the Duke of GLOUCESTER.

LONDON:
Printed for JOHN MILLAN, Whitehall. 1768.
Where may be had, MULLER's Fortification, Artillery, and Mathematics, 8 Vols.

[illegible] Royal. 1829

TO

HIS ROYAL HIGHNESS

The Duke of GLOUCESTER, &c.

THIS WORK

Is moſt humbly Dedicated,

BY

His Royal Highneſs's

Moſt devoted,

Moſt obliged, and

Moſt obedient Servant,

JOHN MULLER.

CONTENTS.

☞ The new Articles are marked with an Asterism *.

* *INTRODUCTION, the origin of artillery* Page i
* *The first guns invented by king* Vitey *in* 85 ibid.
* *Light field pieces introduced by col.* Weideman iv
Experiments on the ranges of guns —— v—ix
Table I, II, III, *length and weight of* French *guns* ix
Gen. Armstrong's *experiments on the length of a* 24 *pounder* xi
General Williamson's *experiments on the best length and charge of an* 18 *pounder* —— —— xiii
The author's experiments with mortars on the best figure of chambers, and on the best situation of the vent xix
Theory of powder, and its application to fire arms xxvi
* *A new construction of* { *brass guns for land service* xxxvi / *light iron field pieces* xxxvii }
A table of the greatest velocities and the greatest ranges, which the different calibers can possibly have xxxviii
A table of the distances that ships may be seen, from one yard to 50, *by the observer's eye, above the surface of the water* —— —— —— xxxix

PART I.

* *Of artillery, containing the weights and measures* 1
Diameters of the shots and bores of guns —— 6
* *Ditto of the* French *expressed by* { *their* / *our* } *measure* 8, 10
* *Table of* { *grape shot, from* 1 *to* 39 *ounces* 12 / *leaden bullets from* 1 *to* 39 *in the pound, according to the author* —— 14 }
The same table according to Sir Jonas Moor — ibid.
The author's experiments on powder measures —— 15
* *Tables of cylindric powder measures, from* 1 *ounce to* 39 *pounds, according to the author* —— 16
* *Tables of ditto* { *when the diameter is to the axis, as* 2 *to* 3 —— —— 17 / *according to Sir* Jonas Moor 18, 19, 20 }

* *Investi-*

CONTENTS.

* *Investigation of a general rule for finding the sums of series's, applied to the finding the number of shot contained in any pile* — — Page 21

* *A table of the number of shot in* 1620 *piles* — 26

PART II.

Construction of guns — — 26

Names of the several parts of a gun — 27

Gen. Armstrong's *construction of brass and iron guns* 29

Examination on the several parts of a gun — 33

General construction for brass battering pieces — 46

To find the weight of metal of a gun — 49

* *Length and weight of old and new battering pieces* 50

Construction of iron battering pieces, with a table of their length and weight — — 52

General construction of iron ship guns — 53

* *A table of their length and weight* — 54

* *General construction of brass ship guns, with a table of the length and weight of old and new* — 56

* *A table, comparing the weight of the old and new guns of all the different rates in the present establishment* 58

* *Number and caliber of guns on board the several men of war* — — — 60

Construction of light field pieces, with a table to compare the length and weight of the present with the new 61

PART III.

Constructions of mortars and howitzes — 65

Dimensions of the present land mortars — 67

Dimensions of sea mortars — — 68

Dimensions of howitzes — — 69

Remarks on the constructions of mortars — 70

General dimensions for new land mortars — 74

Remarks on these dimensions — — 75

To find the weight of metal and powder — 78

General dimensions for howitzes — 80

Weight of howitzes and powder — 82

Of

CONTENTS.

Of sea mortars — — Page 84
General construction of sea mortars — 85
Weight of sea mortars and powder — 86
General construction of shells — — 89
Dimensions of stone mortars — — 91

PART IV.

Construction of { gun — Carriages — 94
Construction of { ship and garrison Carriages — 95
Dimensions of ship and garrison Carriages — 96
General construction of such Carriages — 97
Irons of ship — — Carriages — 99
Construction of travelling Carriages — ibid.
General dimensions of travelling Carriages — 103
Iron work of travelling Carriages — 106
Dimensions of wheels for these Carriages — 108
Tools necessary for loading and proving guns 110
Construction of carriages for light field pieces 112
Dimensions of { a galloper carriage — 115
Dimensions of { limbers — — 116

PART V.

Of mortar beds and howitz carriages — 119
Dimensions of { land mortar beds — ibid.
Dimensions of { sea mortar beds — 123
Dimensions of { an eight inch howitz carriage 124

PART VI.

Different sorts of carriages used in artillery 125
Dimensions of a { tumbrel — — ibid.
Dimensions of a { powder cart — 127
Dimensions of a { ammunition waggon — 128
Dimensions of a { block carriage — 131
Dimensions of a { sling waggon — 134
Dimensions of a { truck carriage — 137
Dimensions of a { travelling forge — 138
Dimensions of a { pontoon carriage — 140
Dimensions of a { pontoon — — 141

The

The gin ——— ——— Page 143
Petards ——— ——— 145

PART VII.

Practice of artillery at home, and service in war 147, 148
Mortar practice ——— ——— 153
Practical rules for horizontal ranges ——— 156
The service of artillery in { *a land engagement* 160
{ *an attack* ——— 163
* *Ricochet batteries* ——— ——— 170
* *Batteries on a glacis* ——— ——— 171
* *Mortar batteries* ——— ——— ibid.
* *Battery* { *in morass* ——— ——— 172
{ *upon a rock* ——— ——— ibid.

PART VIII.

Artillery and stores necessary for a field equipage 175
Quantity of powder and shot for an army ——— 176
Powder and shot for muskets, carbines, and pistols 177
Number of horses used { *for guns* ——— 178
{ *in the campaign of* 1747 179
Stores for the army in 1747 ——— 182
General Belford's *march of the artillery* ——— 191
The manner of forming a park of artillery — 194
Laboratory works ——— ——— 199
Description of { *a fireship, and fitting it up* 206
{ *and manner of preparing stores* 207
Disposition of stores on board, when laid for firing 210
Stores for a fireship of 150 *tons* ——— 212
Composition for preparing the stores of a fireship 213
* *Construction of batteries, with a table of the tools, materials, and number of men, to finish them in one night* 214.

INTRO-

INTRODUCTION.

THE origin of fire arms and artillery is owing to the diſcovery of gunpowder; but when this was, or in what country, we are ignorant of: it is however probable, that it muſt have been in the eaſtern part of the world, becauſe ſaltpetre, which is the principal ingredient, is found in great plenty in ſome provinces on the ſurface of the earth, and from thence is brought to *Europe* ever ſince its uſe has been known; and ſaltpetre being mixed with ſulphur, or ſome other combuſtible ſubſtance, either by chance or otherwiſe, produced a power by its exploſion not known before, whereby bodies could be thrown to a great diſtance.

It is generally ſuppoſed that the *Chineſe* were the firſt that made this diſcovery; for *Ufano Valeſco*, a *Spaniſh* author, mentions, that powder and guns were found in *China* in the year 85, by king *Vitey*; but whether it was known before in any other country is uncertain.

The firſt diſcovery of powder in *Europe* was made by *Bartold Schwartz*, a monk, at *Mentz*, in 1320, by accident; being a chymiſt, he happened to mix ſome ſaltpetre with ſulphur in a mortar, and covered it with a ſtone; the compoſition accidentally taking fire, the exploſion blew the ſtone to a conſiderable diſtance. This ſuggeſted the notion, that if this compoſition was properly confined, it might be uſeful in the attack and defence of places: and from thence the invention of guns may be dated in *Europe*.

 Roger

Roger Bacon, who lived about 50 years before, mentions a composition known in his time, by which thunder and lightning could be imitated: *Schwartz* was the first who applied it to military uses.

It is said that the *Venetians* made the first use of guns at the siege of *Claudia Jessa*, now called *Chioggia*, in 1366, which were brought there by two *Germans*, with some powder and leaden balls; but father *Daniel* proves from records, that the *French* had guns in 1338. As the invention of guns is so immediately connected with that of powder, it could not well be otherwise than that *Shwartz* was the inventor of both; and that they were from thence carried to *France*, and afterwards to *Italy*.

Some authors say, that the first guns were made of iron bars laid lengthways, and kept together with strong iron hoops; and others, with thin sheets of iron rolled up together and hooped; but which way they were made, it must have been in a rude and imperfect manner, like the first essays of many new inventions.

The first guns were but small, and their shot of lead; but afterwards, when their use became better known, they were cast of gun metal, and of extraordinary size; and their shot were made of stone: for the *Turks* had some at the siege of *Constantinople*, that threw a weight of 500 lb. and *Louis* XI. had one cast of the same size; many others are mentioned in history, who carried shots that weighed from 80, 90, to 100 pounds.

But as these guns were so very heavy, and could not be transported without great difficulty, they have been reduced to smaller calibers, and made their shot of iron. Since that time the largest caliber that were used was a 48 pounder; but at present no larger are made in the land service than 24; and at sea 42 pounders.

It was long imagined, that the more powder a cannon was loaded with, the greater its execution would be; for which reason they were loaded with as much powder as their

their ſhot weighed, and to reſiſt ſo great a force, they were made very heavy, and of a great length, in order to give time to the powder to burn all before the ſhot left the piece.

This great charge was diminiſhed afterwards to two thirds, and then to one half, without leſſening the weight of the guns, or their length. The chevalier *Belidor* made ſome years ago ſeveral experiments relating to the charge of battering pieces, whereby he found that one third of the weight of the ſhot was ſufficient, and the *French* uſed no more during the two laſt wars: it is very probable that leſs might do; for ſome experiments were made at *Woolwich* with light field pieces, and it was found that one fourth and even one fifth was ſufficient for the charge of theſe pieces.

Notwithſtanding the great importance it would be to a nation to have its artillery carried to ſuch perfection, as to make uſe of as little metal and workmanſhip as poſſible, and at the ſame time to bring as many and as large calibers into the field as others, thereby reducing its immenſe expence to as little as is abſolutely neceſſary; yet it will be found upon examination, that very little improvement has been made in the proportions of guns ſince *Dilichius*, a *German*, who wrote near 200 years ago.

It is true *St. Remy*, a *French* author, publiſhed in 1723 the moſt compleat and extenſive Treatiſe of Artillery, in two volumes in quarto, that is extant; which has ſince been much improved in the laſt *Paris* edition, in three volumes, publiſhed in 1745, containing all the improvements made in the artillery ſince the firſt edition: but as it is only a collection of memoirs he received from the different artificers employed in theſe works, and who had no other knowledge than bare imitation, it could therefore not be expected that what they tranſmitted to him was grounded upon ſuch mechanical principles as depended upon mathematics, without which no real improvements can be made.

 All

All the authors that wrote ſince have done no more than copied his works in an imperfect manner, even the *German* authors follow him; though it is plain that the *French* have chiefly copied *Dilichius*: for their field carriages are exactly the ſame to this day as he has delineated them in his work; and as to the alterations they have made in the proportions of guns, they are trifling and very little to the purpoſe.

If we conſider the various lengths and weights that have been given to pieces of artillery at different times by all nations, it will appear, that no principle is ſo uncertain and unſettled as that upon which the artillery artificers have grounded their conſtructions. For in queen *Elizabeth*'s time they made ſome 18 pounders 24 feet long, caſcable included, ſuch as the culverin in *Dover-Caſtle*, and that at *Nancy*; and in king *Charles* the ſecond's, Count *Mansfield* made ſome 6 pounders that weighed but 180 lb. and 25 pounders of 700 lb. as is related in the account of the ſiege of *Breda* by the *Spaniards* under the command of *Spinola*; and about the ſame time the *Spaniards* caſt ſome others not much heavier; one of them we had at *Woolwich* was 7 feet long, weighed only 21 : 3 : 4, and carried a ſhot of about 41 pounds of our weight.

Though theſe light pieces were then highly eſteemed for their eaſy carriage and facility of working, yet much heavier and longer have been made ever ſince without any manner of reaſon, till 1744, when Colonel *Weideman*, a *German*, brought light pieces in uſe again as a new invention of his own. His pieces were made of ſheets of copper rolled up and ſoldered together; they were ſo very light, that a 6 pounder weighed no more than two hundred and a half, and yet ſtood all the proofs that were required.

This gave riſe to our light field pieces; but it was not without great difficulty that they were received, and no leſs than the expreſs command of his royal highneſs the late duke of *Cumberland* could have prevailed over the

the servile attachment for an old established custom, though ever so erroneous, which, when once covered by the veil of time, becomes in a manner sacred.

But even lighter field pieces than the present might be used; for on the 12th of *June* 1751, some experiments were made on *Putney-Common* by baron *Stark*, a *German*, with a piece made of a new metal of his invention; which piece was a 6 pounder of 3 feet and a half long, and weighed 3 : 2 : 0, as he said, and it was fired 300 rounds in three hours and 45 minutes, being loaded each time with a pound and a quarter of powder, without receiving the least damage.

This trial being reported to lord *Ligonier*, then master general of the ordnance, he and the rest of the principal officers of the board resolved to try our light 6 pounders, in order to know whether they would stand the same trial or not; and accordingly, on the 15th of *June*, my lord pitched upon one amongst those that had been used at the battle of *Lafeldt*. This piece was four feet and a half long, and weighed 4 : 3 : 0; and after being fired 300 rounds in three hours and 27 minutes, loaded with the same charge as that above, was found not to have received the least damage. The same trial has been repeated afterwards with a gun of the same dimensions as the former, which had been made by another founder, and it succeeded equally as well.

These trials shew, that those light pieces are sufficiently strong for any action ever so obstinate; and that pieces in general may be made lighter than they are at present, appears from several other trials made since with light brass pieces, according to my construction, as will be shewn hereafter.

It is said that such light pieces would not do for battering breaches, nor on board of ships, because of their recoiling too much; but it should be considered, that batteries made upon these occasions are always, or ought to be near the object, and the charges now used are but half the former, because a shot, which has a sufficient velocity

velocity juſt to enter the wall, ſhakes it more and deſtroys it ſooner than if the velocity was much greater. This is a matter of fact grounded upon experience.

It is ſuppoſed at preſent, that no leſs caliber than a 24 pounder will do to make a breach: and it may ſo happen, that the heavy pieces cannot be carried through bad roads, as in *America*, or over high hills, as in *Scotland*. Upon theſe occaſions it ſeems to be abſolutely neceſſary to have light pieces: for which reaſon we have given a new conſtruction of light pieces in page 62, where the weight of a 24 pounder is 18 : 1 : 5; which differs in ſome things from thoſe uſed at preſent: becauſe mine are made the ſame number of calibers long, and their weights in proportion to that of their ſhot, as we ſhall prove hereafter they ſhould be; whereas the large calibers of the preſent are made ſhorter and lighter in proportion than the ſmall; and it has been found by experience, that the preſent light 24 pounders recoil too much, let the hind part of the platform be ever ſo much raiſed.

Artillery has hitherto been conſidered merely as practical, without conceiving that for want of the mechanical principles, deduced from mathematics, no improvements can poſſibly be made. For all the experience of the artillery officers cannot be of any uſe in the conſtruction of pieces, as their buſineſs is to make the beſt uſe of them, and not how they are made, neither are they ever conſulted upon that ſubject.

To put the artillery upon a better footing than it has hitherto been, proper experiments ſhould be made in time of peace, and by ſuch as have ſufficient knowledge, ſo as to be able to draw juſt inferences, which is ſeldom the caſe, as it appears by thoſe hitherto made, and which will be inſerted hereafter, where it will be ſhewn how little the moſt of them may be relied on.

It is certain, that in moſt caſes common geometry and the principles of mechanics is ſufficient; but there are others which cannot be determined without the higher

principles

principles of mathematics. For how can the velocities of ſhots and ſhells be determined, without being acquainted with the laws of reſiſtance, and which cannot be known without the uſe of fluxions, nor the finding the curve deſcribed by the ſhot, which is one of the moſt intricate caſes? Again, the proper length and charges of pieces cannot be determined without the laws of motion in a reſiſting medium: it is true that experiments may be made for that purpoſe; but how far we may depend on them, without being confirmed by a proper theory, will appear hereafter.

A remarkable cuſtom has prevailed all over *Europe*, which is the making ſmaller calibers much longer in proportion than thoſe of a higher nature; imagining, I ſuppoſe, to increaſe thereby the velocity of the ſhot, without knowing that a piece may as well be too long as too ſhort: as long as this pernicious cuſtom prevails, no improvement can be made in artillery; for as a greater number of ſmall calibers are uſed than large, and the ſmall are thereby as heavy again as they need be, were their length of a juſt proportion.

Had it been known that every caliber has but one determined length and charge by which it will carry its ſhot farther than any other greater or leſs, and that it cannot exceed a determined velocity, let the ſhot be impelled by any force whatever, and that theſe velocities are always in proportion to the diameters of the ſhot, this practice would not have been followed. But as the demonſtrations of theſe principles depend on the method of fluxions, which would not have ſo well ſuited in a practical treatiſe as this, I was obliged to write a treatiſe, where every thing relating to artillery, not inſerted here, will be found.

To ſettle artillery upon a proper foundation, we ſhall relate all the moſt remarkable experiments made here and abroad, beginning with thoſe inſerted in *St. Remy's* memoirs, volume i. page 114, which are ſaid to be the oldeſt upon record.

It is easily perceived, that no dependance can be had on these experiments. For it is a plain contradiction, that the point blank ranges of a 24 and 16 pounders should be longer than that of the 33 pounder; and that the random range of these last guns should be no more than that of the 24 pounder. Again, the 16 pounder random range to be so much greater than the rest.

Ranges in Paces.

C lib	Point blank.	At random.
33	600	6000
24	800	6000
16	800	8000
12	450	5000
8	300	3000
4	150	1500

As neither the length and weight of pieces, nor the weight of the charges are mentioned, though the experiments were true, no useful inferences can be drawn from them.

Monsieur *du Metz*, lieutenant general, made in his time the following experiments on the ranges of guns, by which he found that the *French* pieces loaded with two thirds the weight of the shot, and those of the new invention loaded with one third, ranged the same distances when elevated at an angle of 45 degrees.

Calib.	Ranges.
24	2250 Toises
16	2020
12	1870
8	1660
4	1520

As neither the length or the weight of the pieces are mentioned, nothing can be concluded from these experiments. It is surprizing that *St. Remy* did not mark the dates of these experiments, nor what the *French* pieces were at that time, as well as those of the new invention. If I may venture to guess, their length were 10 feet, all except the 8 and 4 pounders, which were only 8 feet, according to the second table hereafter; and those that are called of the new invention had spherical chambers.

If

If this be true, all that can be concluded is, that 10 feet is a better length for a 24 pounder than for any other caliber, when loaded with a weight of powder equal to the two thirds of their ſhot; but as no piece is loaded at preſent with that charge, theſe experiments can be of no uſe.

There are ſeveral tables of the lengths and weights of the *French* pieces uſed at different times not ſpecified, except the laſt of the preſent.

That which ſeems the oldeſt is the following, pag. 73, volume i.

This table ſhews how rude and imperfect the firſt trials of artillery were, and what enormous length the ſmaller calibers were made in thoſe times.

It is alſo to be obſerved, that the 24 pounder, tho' 13 feet long, weighed no more than 4300 lb. whereas the preſent of 10 feet weigh 5400 lb. If the former were found to be ſufficiently ſtrong, what could induce them to load them with ſo much metal now? All that can be ſaid is, that if experiments are made for a particular fancy only, and are not enquired into by the ſucceſſors, all the attempts an author can make for improvement are vain and uſeleſs to the public.

TABLE I.

Calib	Length. Feet Inch.	Weight.
48	10 : 0	7200lb.
40	16 : 6	7000
32	22 : 0	7200
24	13 : 0	4300
20	16 : 0	7000
16	18 : 0	4200
12	11 : 0	4250
10	13 : 0	3850
8	15 : 0	3500
4	12 : 6	2500

In the table facing page 207, vol. ii. are marked the following dimensions.

TABLE II.

Calib.	Length.	Weight.
33	10 : 0	6200lb.
24	10 : 0	5100
16	10 : 0	4100
12	10 : 0	3400
8	8 : 0	1950
4	8 : 0	1300

This table shews, that the length and weight of pieces were better proportioned in that time than they were before: but that the length of the 24 and 16 pounders should be the same as that of the 33; as likewise the 8 and 4 to be of the same length, shews the little reasoning made use of in that time.

The last regulations that were made in 1732, and which are followed at present, may be seen in the next table. It is evident, that the lengths and weights were not deduced from any solid reason, but from the fancy of those who are most at the head of that branch.

TABLE III.

Calib.	Length.	Weight.
24	10 : 1.5	5400lb
16	9 : 6	4200
12	9 : 0	3200
8	8 : 1	2100
4	6 : 9	1150

That the weight of these guns is greater than they need be, appears from our iron 24 pounders weighing no more than 4800, which is even too much, as will be shewn hereafter; and according to this proportion, the set of them contains 3250 lb. of metal more than the strongest construction requires.

It must be observed, that the *French* reckon by the neat weight, and not by 112 pounds for a hundred weight, as we do; but it is shewn in page 11, that 100 *French* pounds weigh something more than 114 of our

our pounds; so that a *French* hundred neat weight is more than our hundred of 112 pounds.

We shall now come to the experiments made at home, or under the direction of *English* officers. The first on record that came to my knowledge are those made by general *Armstrong*, surveyor general, in 1736, which are:

The length of these pieces are expressed in feet and inches, and the ranges in yards: out of a great many trials, three of the longest ranges of each piece are set down here. All these pieces were brass 24 pounders, and all weighed nearly 5200, and were always loaded with two thirds of the shot's weight, that is, with 16 pounds.

Length.	Range.	Range.	Range.
10 : 6	2486	2614	2406
10 : 0	2570	2532	2436
9 : 6	2633	2560	2500
9 : 0	2796	2494	2563
8 : 6	2586	2490	2466
8 : 0	2438	2470	2453

The intent of these experiments was to find the best length for a battering piece, when loaded with the common charge then given; and that of 9 feet 6 inches was fixed upon as the best, though the first and last of the 9 feet ranges were the longest of those in the same columns: this was owing, I suppose, to this length being more convenient for battering than that of 9 feet long.

If we examine strictly into these experiments, it will be found, that no improvement can be made from them. For no two guns can be equally bored, and the least difference may cause a considerable one in the ranges: nor no two vents can be pierced so as to come out at the same distance from the bottom of the bore, which is of the greatest consequence, as we shall prove from repeated experiments.

Length

Length.	Number.	Elevation.	Ranges in Yards.	Powder.
11 Feet.	1	6 Degrees.	1780	9 Pounds of Powder.
	2		1750	
	3		1725	
	4		1725	
9 Feet.	5		2000	
	6		1830	
	7		1965	
	8		2018	
11 Feet.	9	7 ¼ Degrees.	1860	
	10		1935	
	11		1960	
	12		2048	
9 Feet.	13		2060	
	14		2165	
	15		2050	
	16		2272	
11 Feet.	17	10 Degrees.	2490	
	18		2395	
	19		2567	
	20		2670	
9 Feet.	21		2910	
	22		2780	
	23		2790	
	24		2577	
11 Feet.	25	12 Degrees.	3016	
	26		2720	
	27		2800	
	28		3000	
9 Feet.	29		2712	
	30		2910	
	31		2955	
	32		3070	
11 Feet.	33	15 Degrees.	3185	9 Pounds of Powder.
	34		3095	
	35		3400	
	36		3185	
9 Feet.	37		3532	
	38		2940	
	39		3460	
	40		3725	
11 Feet.	41	10 Degrees.	2550	10lb.
	42		2377	
	43		2365	
	44		2575	11lb.
	45		2495	
	46		2375	
	47		2520	12lb.
	48		2605	
	49		2645	
	50		2730	10lb.
	51		2380	
	52		2445	11lb.
	53		2200	
	54		2780	12lb.
	55		2550	
9 Feet.	56	45 Degrees.	4160	9 Pounds.
	57		4135	
	58		4100	
	59		3970	
	60		4015	
	61		3980	
	62		3700	
	63		3960	10lb.
	64		3945	
	65		3785	11lb.
	66		3930	
	67		3802	2lb.

But

But ſuppoſing all the pieces were exactly bored alike, and the vents placed the ſame, what other concluſion could be drawn from theſe experiments, than that the beſt length of a 24 pounder is 9 feet 6 inches when loaded with 16 pounds of powder? It is not probable, that if a leſs charge was uſed, as at preſent is the caſe, this length would be the beſt; neither can we draw any inferences from them in reſpect to the length of greater or ſmaller calibers.

It is not ſufficient to make experiments without any intention of their being uſeful towards the improvement of artillery in general, and ſuch as proper concluſions may be drawn from them; otherwiſe the greateſt uſe they can be of, is to determine ſome particular caſes only, which are by no means ſufficient.

The beſt and moſt uſeful experiments that have hitherto been made, are thoſe of general *Williamſon*'s, aſſiſted by major *Hiſlope*, and ſeveral other officers of artillery, which I ſhall inſert here, as taken from major *Hiſlope*'s account.

Experiments made at *Mahon* in *Minorca* in 1745, with two iron 18 pounders, one of 11 feet long, which weighed 51 : 0 : 5; and the other of 9 feet weighed 39 : 1 : 3. They were fixed upon a rocky ground, and ſo contrived as to be elevated to any number of degrees.

Hence it appears, that when the pieces were loaded with 9 pounds of powder, the range was greater than when loaded with more or leſs.

Again, that the pieces of 9 feet long carried farther than thoſe of 11, in almoſt all the ſame circumſtances, though the firſt is lighter than the ſecond; which ſhews that the length of the ranges does not ſo much depend on the weight, as on a proper length, and on a proper charge.

The accuracy of theſe experiments is confirmed by the theory: for we have proved in our appendix, that the greateſt range an 18 pounder can have, when elevated to 45 degrees, cannot be quite equal to 4190

yards,

yards, becauſe we have ſuppoſed ſuch a velocity as the ſhot cannot poſſibly have, but may continually approach it.

Now as the greateſt range in theſe experiments is 4160 yards, which differing only by 30 yards, the computed ones evidently prove the accuracy of theſe experiments; and it proves with no leſs certainty, that 9 pounds of powder communicated the greateſt velocity to the ſhot that it poſſibly could receive by any force whatever.

When thus experiments agree with a theory founded upon unexceptionable principles, there cannot remain the leaſt doubt of their certainty.

As 9 feet is nearly 21 diameter of an 18 pounder ſhot, and 9 pounds of powder half the weight of the ſhot; and it is preſumed that pieces, whoſe lengths and charges are proportional, will have their ranges likewiſe ſo; becauſe their greateſt velocities are proportional to the diameters of the ſhot, as we ſhall prove in the appendix: we may conclude with ſome degree of certainty, that if the length of a piece of any caliber be 21 diameters of its ſhot, and loaded with powder equal to half the weight of the ſhot, it will carry farther than any other of the ſame caliber, either longer or ſhorter, loaded with any charge whatever.

Thus we have at laſt determined that important queſtion in artillery ſought for ever ſince its invention; but to be entirely convinced of the truth of our determination, more experiments of this kind ſhould be made with various calibers; but care ſhould be taken that they may not be liable to any exception.

The moſt certain way of proceeding, in my opinion, would be, to caſt a gun of any caliber of 22 diameters of its ſhot long; to examine whether it is truly bored, and that the vent comes exactly out at the bottom of the bore; then let it be fired with various charges and elevations, till there is a ſufficient proof of its beſt charge; this being done, a part of the piece muſt be ſawed off the length of its diameter, and the firſt trials

repeated

repeated as before: and when the beſt charge and its range are aſcertained, the length of the piece muſt be diminiſhed again by the length of the diameter of its ſhot. Theſe trials being continued till the greateſt ranges diminiſhes, then the beſt length and charge will be aſcertained of that caliber; and thoſe of any other caliber may be found in the ſame manner. The only care to be taken in theſe experiments, is to mix well the powder, and to dry it in the ſun, that it may have always the ſame ſtrength as nearly as poſſible: another caution muſt be taken, which is, to make theſe experiments in clear and ſerene weather, and of the ſame heat, becauſe the powder will act more violently in a cold froſty morning than in hot weather, as we ſhall ſhew.

Though it is proper to know the beſt length and charge of a piece, yet in real ſervice their length depends moſtly on the uſe they are made of, according to the different circumſtances: thus ſhip guns ſhould be ſhort and light, ſo as to be eaſily houſed and loaded, becauſe the rammer handle is made of rope; in long pieces it muſt be bent, which requires great care to ram the powder and ſhot home; and when this is not done, the priming fires without the powder, which is always in cartridges; the ſailors thinking that the ſhot was diſcharged, load it again, and miſs firing as before. This has been found ſo for three times running, and when at laſt the powder in the firſt cartridge takes fire, often burſts the gun, and deſtroys the ſailors placed near to ſerve it; whereas when the guns are ſhort, the rammer handles may be made of wood in all ſmall calibers, and the ſervice become more expeditious. Beſides, ſhips now come ſo near to one another, that the ſhots are not required to go ſo far; provided it takes place it is ſufficient.

The only objection againſt light guns is, that if they recoil too much, they will be apt to tear their tackle; but it has been found by experience, that half the uſual charge is quite ſufficient, and perhaps leſs. If then the charge is diminiſhed, the weight of the gun may like-

wiſe

wiſe be diminiſhed, without increaſing the recoil. This ſhould however be done with diſcretion, and not without proper trials; for hazards ſhould be avoided as much as poſſible.

Field pieces or battalion guns ſhould be ſhort and light, in order to be able to advance or retreat as faſt as the army; ſuch are thoſe we make uſe of at preſent, with very little alterations in the calibers above a 6 pounder.

Battering pieces, on the contrary, ſhould be of a proper length to enter into the embraſures, that by their blaſts they may not deſtroy them too ſoon, becauſe it cannot be prevented entirely; for which reaſon the gunners repair them every evening when it is dark.

With regard to garriſon pieces, their length ſhould be ſuch as that the ſhot may go fartheſt, becauſe in a ſiege they will oblige the beſiegers to open their trenches at a greater diſtance, which is generally without gun ſhot; and in a fort placed near a navigable river, or the ſea, they will reach the ſhips, when the ſhips cannot reach the fort.

For theſe reaſons we make in our new conſtructions the length of light field pieces 14 diameters of their ſhot, the ſhip guns 15 of thoſe diameters, and the battering as well as the garriſon pieces 21; whereby the 24 pounder for battering becomes 9 feet 8 inches long, which is 2 inches more than the uſual length. We might likewiſe uſe a 32 pounder, which, according to our conſtruction, page 52, would weigh but 5400, that is, only 200 more than our preſent braſs 24 pounder.

The intent of the following experiments, which I made in 1753 with two ſmall mortars, was to find the propereſt place of the vent, and the beſt figure of the chambers: their bore was three inches, and 7.5 long; one had a cylindric chamber of one inch diameter, and two long; the other a concave in the ſhape of an egg, with a ſmall cylindric entrance of half an inch diameter, and the inſide terminated by a ſharp edge. Both theſe chambers held an ounce of powder at firſt, but widened

by

by firing so as to hold an ounce and a quarter afterwards. Each had two vents, one in the middle, and the other at the bottom; I had a screw to stop one when the other was used: the mortars weighed 36 pounds each, and the shells 2 pounds 7 ounces at a medium. We have not marked the angles of elevations, because they were unnecessary, only so far as that they were the same, when the lower and upper vents were compared.

Pdr.	Vent	Cylind.	Concave	
One Ounce.	Middle.	630	750	Loaded with the common shooting powder. Weather cool in the morning, and sultry afterwards.
		630	730	
		600	686	
		550	722	
		560		
	Lower.	806		
		900		
	Middle	800	889	With common ordnance powder. Weather warm and windy.
		756	875	
		864	877	
1¼ Ounces.	Lower.	1100	1194	With the best ordnance powder. Weather warm and windy.
		1023	1088	
		1003	1131	
		1020	1122	
		1020	1200	
		Ranges in Yards.	Ranges in Yards.	

Colonel *Desaguliers* and myself made several other experiments, together with a mortar of the same size that had several shifting chambers. The substance of what was most remarkable in them are as follows:

A narrow cylindric chamber of about four inches long holding 12 grains of powder, being loaded with 6 grains by means of a thin cartridge: when the powder was placed close to the shell, so as the lower part of the

chamber

chamber was empty, and fired by means of a quick match introduced through the vent; and after this, it was loaded again with the ſame charge placed at the bottom of the chamber, and the empty ſpace between the ſhell and the powder; the ſhell went near twice the diſtance in the firſt experiment that it did in the ſecond, and when the powder was placed in the middle of the chamber at an equal diſtance from the bottom and the ſhell, the diſtance or range was a mean between the two former. Theſe experiments were frequently repeated, and the ranges in the firſt caſe were always nearly double thoſe in the ſecond. From what cauſe it may proceed that the ſame quantity of powder, placed in the ſame ſpace, ſhould produce ſuch various effects, is not in my power to conjecture.

The ſame mortar being loaded with the ſame quantity of looſe powder, I put a little piece of writing paper upon it, by which the ſhell went much farther than when loaded with the ſame quantity of powder without paper.

Three cylindric ſhifting chambers of different lengths holding the ſame quantity of powder, produced the ſame range when full; but when they were not quite filled, the longeſt produced the greateſt range.

Two chambers in the form of a fruſtum of a cone, the largeſt baſe was at the bottom in one, and the ſmalleſt of the other; the firſt carried the ſhell farther than the ſecond.

The colonel tried two experiments more; the one between grained and mealed powder; and they were both found to be of an equal ſtrength: and the other he put a ſmall phial filled with water into the chamber amongſt the powder, and found its ſtrength conſiderably increaſed; that is, the ſhell went farther with the water than without it. The colonel tried likewiſe a cylindric chamber of about four inches long, with four vents, one at the bottom, one at the upper end, and two in the

the middle, all four at an equal diſtance from each other, ſo that when one was uſed, the others were ſtopped by ſcrews; and he found that the loweſt carried the ſhell fartheſt, and the ranges of the others diminiſhed in proportion as they were diſtant from the bottom.

Many uſeful obſervations may be made on theſe experiments. Firſt, that the vent placed near the bottom of the chamber is more advantageous than any where elſe; though this has been found ſo in mortars, we are not certain that it is the ſame in guns, which ſhould therefore be tried; and if it be found the ſame, the query is, whether the bottom of the bore ſhould not be flat, inſtead of roundiſh, as is the cuſtom, or to pierce the vent from the breech moulding, as colonel *Weideman* did, or elſe as the *French* do in ſome of their mortars, with a ſmall cup at the end of the chamber to receive the vent. From hence it appears how inaccurate experiments have hitherto been made, and how neceſſary it is to make new with all the neceſſary precautions, in order to improve artillery, and to bring it to perfection.

Before theſe experiments were made, it was imagined, that when the vent is in the middle of the chamber the range would be the greateſt, becauſe if a tube filled with powder was lighted in the middle, the powder would be burnt in half the time it would if lighted at one end, and it was ſuppoſed that the greater quantity burnt before the ſhot was ſenſibly moved from its place, the greater force it would receive; but notwithſtanding this plauſible reaſon, experiments have evinced the contrary.

The next obſervation to be made is, that the concave chamber is preferable to the cylindric, and this to any other; which has not hitherto been conſidered: the *Spaniards* make theirs ſpheric, the *French* in the ſhape of a pear; and we conical. The various opinions authors and artilleriſts have concerning the figure of chambers are very extraordinary. The chevalier *Belidor* eſteems the conical the beſt; but his reaſoning concerning the pro-

perties of different chambers in page xxiv. of his *Bombardier François*, are so very weak and inconsistent, that it is needless to answer them: how so great a man as he is in all other respects could descend to such vulgar errors is inconceivable.

Mr. *Robins*, in page 41, old edit. pretends, that the figure of a chamber has no effect upon the action of powder, without shewing the least reason for his assertion. Count *Bukeburg* will have a parabolic form, imagining, that if the fire was introduced to the focus, the rays of lighted powder would, by the nature of the figure, reflect into parallel direction in the same manner as the rays of light: supposing this was true, the shell would not receive a greater force by it, because a fluid acts always in a perpendicular direction to the surface it strikes; thus in a globe the directions of the fluid tend all to the center, as we shall prove in the fifth theorem; and when all the forces are reduced to the direction of the shell, it is that force reunited into one direction that produces the real effect, and not the partial ones. This not only refutes what his lordship said, but likewise *Belidor* and *Robins*, as having all split upon the same rock. It is not the inward figure of the chamber, but its entrance, which produces the effect; because the smaller it is, the nearer it reduces the effect into the direction of the shell. This is likewise proved by the practice of making sky-rockets, which being choaked at the end, by which it confines the force of explosion into a narrow stream, and increases its violence so as to make the rockets rise so high as they do; whereas if the opening was not confined, they would scarcely rise at all. The notion that a concave chamber with a narrow neck shakes the mortar violently without increasing the force of explosion, or the range, is so inconsistent with the laws of motion, that it merits not the least attention.

It is the general opinion of the artillery officers, that a mortar or gun carries farther when it is warm by much firing than when cold, or in the heat of the day than in the

the morning. The constant practice by sea and land is, that when the guns are much heated to diminish their charges, from the notion that they carry them much farther; which is a mistake. For when guns are much heated, they are liable to be spoiled; and it is prudent to lessen their charges in that case. For it appears from my first four experiments made in the cool of the morning, that the ranges were greater than those when the weather grew warm. The chevalier *Belidor* made several experiments for that purpose, which I have seen, and which are mentioned in general only in his *Bombardier*, page xxxviii; but the particulars are as follows: several mortars were fired in the cool of the morning; the same trials were repeated in the middle of the day when it was very hot, and the ranges in the morning were always greater than those in the heat of the day: but as this was not sufficiently satisfactory, the chamber of a mortar was heated with lighted charcoals as hot as could be without endangering the powder from taking fire; the range in this state of heat was much shorter than when the mortar was quite cold. It is true that heat will dry the powder, and gives it a greater force, if it remains a certain time in the chamber, which is not the case in brisk firing; and dried powder is better than when it is damp; yet the elasticity of the air is much increased by cold, and relaxed by heat; I mean from the state of the atmosphere.

Having said every thing necessary in respect to the length of guns, we are now to consider their thickness or strength of their several parts, which should be proportional to the efforts of fired powder; but its absolute force cannot be determined otherwise than by experiments. The weight of the guns depends on the charge of powder; and on their length; and though the charge has been lessened from that given formerly, yet the thickness of metal remains in general the same; nor have the experiments with light guns mentioned before,

prevailed as yet in diminiſhing the weights of larger calibers.

I had two braſs 12 pounders caſt for admiral *Keppel*, according to the conſtruction in page 54; they weighed 13 : 1 : 0, which ſtood the full ordnance proof; the old weigh 29 : 1 : 0.

I had alſo ſeveral eighteen braſs pounders caſt for the *India* company; ſome of them were lately proved at *Woolwich* with fifteen pounds of powder, though the charge in ſervice ſhould not exceed ſix pounds: they weigh 2400, and are 9 feet long: a 24 pounder would in the ſame proportion weigh 3200, and their length 9 feet 8 inches. I look upon this proportion to be ſufficiently ſtrong for braſs battering pieces, though much lighter than the preſent; even a 32 pounder of that length would weigh only 4200, and in my opinion make better battering pieces; becauſe the largeſt ſhot makes a breach ſooner than a ſmaller, and the ancients made uſe of 48 pounders for that purpoſe; but on account of their unweildineſs they were reduced to 24 pounders, not that they were better, but more manageable. That theſe guns are ſufficiently ſtrong appears not only from their proof, nor that they weigh twice as much as thoſe of the light nature; but likewiſe from ſome old 32 iron pounders caſt in king *Charles* the ſecond's time; ſome of them remain ſerviceable to this day, and they weighed 4200 only.

The firſt caſt guns were made of what is called gun metal, and this metal continued for a great while before caſt iron was uſed; but in time, as artillery became more in uſe, the number of cannon became very great, and to leſſen the expence iron guns were invented; but the opinion of their being liable to burſt when much heated by firing, was the cauſe of making them heavier than the braſs; and as ſome did burſt in effect, either through wrong management, or the unſkilfulneſs of ſome founders, this notion has prevented the more general uſe that might be made of them to this day. But for what

reaſon

reaſon we make them much heavier now than in king *Charles*'s time cannot be accounted for; for the preſent 32 and 42 pounders weigh 54 and 55 or 56 hundreds; whereas they weighed formerly only 4200 and 5200. This cannot be owing to better ore, or to more ſkilful founders; becauſe I have ſeen iron caſt by the *Carron* company that could not be broke by any means, but would flatten and tear like braſs. I had two iron three pounders caſt by that company for lord *Egmont* that weighed 3 : 3 : 0 each, which ſtood the full ordnance proof with three pounds of powder; whereas their charge in ſervice ſhould never be more than one fourth, or at moſt one third of that quantity. I had ſince two ſix and two twelve pounders caſt by the ſame company for the *Portugueſe* ſervice; the firſt weighing 7 : 3 : 0, and the others 15 : 2 : 0; and though they are not yet proved, I will anſwer for their ſtrength. The old 6 pounders weigh 17 : 1 : 0, and the 12 pounders 32 : 2 : 0.

That iron pieces are preferable to braſs evidently appears from the experience we had in the laſt war; for at *Belleiſle* the braſs guns were ſoon rendered uſeleſs, and iron ſhip guns were uſed to finiſh the ſiege. I have been aſſured by ſeveral artillery officers, that in all the ſieges we made in the laſt war, they were obliged to uſe iron guns, becauſe the braſs did never ſtand great firing, though they weigh 400 more than the iron.

This is eaſily accounted for, becauſe gun metal is a compoſition of copper and tin; the copper requires a red heat to melt, and tin only a common fire; ſo that when the gun is heated by much firing, the tin melts, and the copper alone remains to ſupport the force of exploſion; by which the muzzle droops, and the vent widens ſometimes to that degree, as a man's fiſt may go in it. To make the vent more durable they put in a piece of copper to grain it, as it is called. This grain is fixed into the mould before the melted metal is let in to make them unite together; but as copper is ſofter than gun metal, inſtead of making the vent more

durable, as it is imagined, it rather weakens it in my opinion. If a ſteel grain was put in, provided it can be united with the metal, there is no doubt but it would be better than any other metal; for it has been found by experience, that a new vent of iron being made, it was ſcarcely ever ſpoiled afterwards. The *French* had a gun with an iron vent at *Belleiſle*, which was found after the ſiege to be the only one that ſtood out the ſiege without being ſpoiled. To make a compoſition of gun metal of a durable ſubſtance, the ingredients ſhould be ſuch as require the ſame degree of heat to melt; but no ſuch metals have as yet been diſcovered. It is true, that ſome *Saxons* pretend to have that ſecret; but as they have not yet made any guns of it, no dependance can be made on it.

As good iron caſt from virgin ore has all the quality that can be deſired in gun metal, and not one burſt all this war that I heard of, what occaſion is there for any other? and there is ſuch a plenty of it every where, eſpecially in *England*, and the founders are ſo expert in their buſineſs at preſent, that they can make it more or leſs malleable, as they pleaſe; beſides, the expence is ſo much leſs, as 9 or 10 to one; which one would think ſhould be a ſufficient motive to uſe no other. Although the artillery officers agree, that iron battering pieces are preferable to braſs, yet to make field pieces of iron they by no means approve of, becauſe they ſay it would be too dangerous to ſtand by them in time of action; but what ſhould prevent a proper trial to be made? And if it does not ſucceed, the expence would be inconſiderable; and if it does, as I do not doubt it will, what a prodigious expence would be ſaved.

I would adviſe to have two ſix pounders caſt of the ſame weight as the braſs, and proved in the ſame manner; then fire them three hundred rounds as quick as they can, with a pound and a quarter of powder, in the ſame manner as the braſs were tried; and if they ſtand ſuch a trial, let the officers then judge whether there can

be

be any danger in uſing them. We are not to judge raſhly in a matter of ſo great importance as this, without a full and ſufficient proof. It is not the opinion of a few perſons we are to judge by, but by matter of fact. I may poſſibly be miſtaken, though I think to have ſufficient proofs of what I aſſert; and therefore recommend proper trials to be abſolutely certain.

As we propoſe chambers to be made in all calibers from an 18 pounder upwards, it will not be improper to ſhew here their advantage, firſt from experiments, and afterwards from theory. General *Williamſon* and the reſt of the artillery officers made likewiſe ſeveral experiments with ſhells from a bomb veſſel in the harbour of *Mahon* in 1746. Of which I ſhall only inſert the range of the fifth, which was 4570 yards; the mortar was loaded with 35 ℔ and 10 ounces, the ſhell weighed two hundred or 224 pounds, and the angle of elevation 45 degrees; and the range of the ſeventeenth experiment with a ten inch mortar was 3787 yards; the ſhell weighed 97 lb. and the mortar loaded with 12 pounds of powder. Now the charge of the firſt mortar being about 5.6 parts of the weight of the ſhell, produced a greater range than the 18 pounder gun loaded with half the weight of the ſhot; the ſecond mortar was loaded with no more than an eighth part of the ſhell's weight, and yet its range differed but 373 yards from that of the gun. This great difference between the forces of powder, when it was confined in a chamber, and in a gun without a chamber, can ariſe from no other cauſe, than that the direction of its force is nearer to that of the ſhell than it is to that of the ſhot. It is true, that the reſiſtance of the air is leſs on the ſhell than on the ſhot; but, on the other hand, the bore of the mortar is ſo ſhort, and ſo wide in compariſon to the width of the chamber, that the exploſion of the powder can only act upon the ſhell before it is ſenſibly moved from its place; inſtead of which it acts upon the ſhot till it leaves the gun. All this being conſidered, the advantage

tage of chambers in guns, as well as in mortars, will be found to be very conſiderable.

We ſhall prove this likewiſe by theory hereafter in theorem the vth.

Though we have ſhewn that the theory of powder is as yet defective in many reſpects for want of a ſufficient number of good experiments, thoſe which have hitherto been made were with too ſmall quantities, as can by no means be depended upon; ſince the ſmalleſt error in a few grains becomes very conſiderable in the charges of artillery pieces; neither do we know the time of the degrees of inflammation. All that can be done, is to ſuppoſe that it fires all at the firſt inſtant, and proceed upon this ſuppoſition, though erroneous, till ſuch time that the law of inflammation has been diſcovered.

THEORY of POWDER.

THEOREM I.

The exploſion of fired powder produces a permanent elaſtic fluid, and forms a ſphere, if not prevented by any external obſtacle.

AUTHORS agree, and experience ſhews, that fired powder produces an elaſtic fluid; and if it be fired under an exhauſted receiver, the mercurial gage deſcends; and though it riſes again when the heat is abated, yet it remains always below its common ſtandard; which plainly ſhews, that the fluid produced by fired powder is elaſtic and permanent.

Again, if a ſmall quantity of powder be fired on a table, its flame riſes in the form of a ſemi-ſphere; and in whatever veſſel powder is confined, the exploſion will always burſt it in the weakeſt part, if the elaſtic force

be

be ſufficient. Conſequently fired powder acts on every ſide alike; which could not happen, unleſs the exploſion was ſpherical.

Remark.

Though authors agree, that powder produces an elaſtic fluid when fired, yet they differ in the manner of it. Moſt of them are of opinion, that powder is only condenſed air, which being heated by the exploſion, as well as the natural air contained between the interſtices of the grains, produces this elaſtic fluid. Others affirm, that the air contained in powder exiſts in its natural ſtate; which being heated expands itſelf, and produces the exploſion. But this is contradicted by the above-cited experiment: for when the heat in the receiver is abated, the mercurial gage ſhould, according to this ſuppoſition, riſe again to the ſame height as it was before; which is contrary to experience.

Sir *Iſaac Newton* ſays, in his *Optics*, Query 10, that if ſalt of tartar be mixed with powder, and that mixture be heated till it takes fire, the exploſion will be more violent and quick than that of powder alone; which can proceed from no other cauſe, than the action of the vapour of the powder upon the ſalt of tartar, whereby that ſalt is rarefied; and therefore the exploſion of powder ariſes from the violent action, whereby all the mixture being quickly and vehemently heated, is rarefied and converted into fume and vapour; which vapour, by the violence of that action becoming ſo hot as to ſhine, appears in the form of flame. Thus far Sir *Iſaac Newton*.

But whether the elaſtic force of powder be owing to the expanſion of air, or to ſome other fluid produced by the ingredients of which it is made, is not material in reſpect to what follows; it being ſufficient for our purpoſe, that the force produced thereby acts chiefly according to the ſame law as all other elaſtic fluids; which it will be proved to do by experiments hereafter.

THEOREM

THEOREM II.

The densities of the same quantity of an elastic fluid, contained in different capacities, are as these capacities inversely.

For the same quantity of matter being reduced to half the bulk, will have its parts twice nearer each other; if it be reduced to one third or one fourth of the bulk, the parts will be three or four times closer to each other; and whatever the bulk is reduced to, the parts will always be closer to each other in the same proportion. And since the density of matter consists in the closeness of the parts, it is evident that the density increases as the bulks diminish; consequently, the densities of the same quantity of an elastic fluid, contained in different capacities, are as these capacities inversely.

COR. I.

Hence it follows, that the densities of different quantities of the same elastic fluid, contained in the same or equal capacities, are as these quantities. For if twice the quantity be contained in the same capacity, the density will be double; if three or four times the quantity be contained in the same capacity, the density will be triple or quadruple; and therefore, in general, whatever the ratio is between the quantities contained in the same or equal capacities, that of the densities will always be the same.

COR. II.

Hence the densities of different quantities of the same elastic fluid, contained in different capacities, are as the quantities directly, and the capacities inversely. For because the densities of the same quantity of an elastic fluid,

fluid, contained in different capacities, are as these capacities inversely, by Theorem II. and the densities of different quantities of the same fluid, contained in the same or equal capacities, are as these quantities directly by Cor. I. it is evident, that if the quantities are different, as well as the capacities, the densities will be as the quantities directly, and the capacities inversely.

THEOREM III.

The intensity of heat produced by the explosion of fired powder, will be as the density of the fluid.

For the heats of the same quantity of powder, fired in different capacities, will be as these capacities inversely; and the heats of different quantities, fired in the same or equal capacities, are as these quantities directly. Therefore the intensity of heat produced by different quantities of fired powder in different capacities, is as the quantities directly, and the capacities inversely; or as the densities by the last Corollary.

THEOREM IV.

The elastic force produced by an explosion of fired powder, is in the compound ratio of the density of the fluid, and the intensity of heat.

For the elastic force of condensed air is as the force of compression, and the force of compression is as the density; and since the elastic force is also increased by heat, it is manifest, that the elastic force is in the compound ratio of the density of the fluid, and the intensity of heat.

This may likewise be proved as follows: since every particle of the fluid has the same degree of heat, and the total force of the explosion is equal to the sum of the forces of all the parts; the elastic force of the explosion

plosion is therefore in the compound ratio of the heat of one particle, and the sum of all the particles, or, which is the same, the density of the fluid. Consequently the elastic force, produced by the explosion of fired powder, is in the compound ratio of the density of the fluid, and the intensity of heat.

REMARK.

Mr. *Robins* supposes the elastic force, produced by the explosion of fired powder, to be as the density of the fluid, which is the case of condensed air void of heat; and therefore he supposes the increase of force, produced by heat, to be constant, in his proposition; but finding afterwards that the force increased by heat, he says, we have hitherto supposed powder, when fired, to be equally hot with iron, at the beginning of its white heat; but we have observed, that it varies according to the quantity of powder fired together. The flame therefore may have all the different degrees, from that of a languid red heat, to the heat sufficient for the vitrification of metals; which agrees exactly with what has been said in the last Theorem. That heat increases greatly the elasticity of air, is known by heating an empty bottle, well corked, in boiling water; for it will either drive the cork out, or else burst the bottle. It is likewise well known, that the steam of boiling water produces a great elastic force, and perhaps more than fired powder; although cold water seems to be intirely void of elasticity, since it cannot be compressed by any force we know of. Hence it seems as if cold water was in its densest state; and it appears very probable, that the density of air has its limit, beyond which it never can be reduced.

COR. I.

Since the intensity of heat is as the density of the fluid, by Theor. III. and the elastic force of fired powder

der is in the compound ratio of the denſity of the fluid, and the intenſity of heat, the elaſtic force of fired powder is therefore in a duplicate ratio of the denſity; and, conſequently, by Cor. II. of Theor. II. the elaſtic force of fired powder is in the duplicate ratio of the quantity of powder directly, and the duplicate ratio of the capacities inverſely.

Cor. II.

Hence, if the quantities of powder are in the ſame ratio as the capacities in which they are contained, the forces of exploſion will be equal.

For ſince theſe forces are in the duplicate ratios of the quantities of powder directly, and the duplicate ratio of the capacities inverſely; the ſingle ratios being equal by ſuppoſition, the duplicate will likewiſe be equal.

Cor. III.

By a known property of fluids in general, the preſſure againſt any ſurface is in the compound ratio of the impreſſing force, and the ſurface preſſed; and ſince, of all equal ſolids, the ſphere has the leaſt ſurface, it is evident, that of all capacities which contain the ſame quantity of powder, the ſpheric is the ſtrongeſt, or, which is the ſame, is the leaſt preſſed.

Cor. IV.

Hence, the forces againſt ſpheric ſhells, filled with quantities of powder proportional to their capacities, are to each other as the ſquares of their radii; for the forces of exploſion being equal by Cor. II. the forces againſt theſe ſhells will be as the ſurfaces preſſed; and they being as the ſquares of the radii, the forces impreſſed will be in the ſame ratio of the ſquares of the radii. Conſequently, if the thickneſs of ſhells are proportional

portional to their radii, they will be equally ſtrong, ſince their thickneſs will be to each other as the ſquares of the radii, and conſequently as the impreſſing forces.

Cor. V.

It is alſo manifeſt, that the forces againſt the concave part of the cylindric ſurfaces, filled with proportionable quantities of powder, are as theſe ſurfaces: for the forces of exploſion are equal in this caſe, by Cor. II. and therefore the impreſſing forces are as the ſurfaces preſſed. Now becauſe cylindric ſurfaces are in the compound ratio of their radii and their axes; if the axes are equal, the forces are as their radii; if the radii are equal, as their axes; and if they are ſimilar, as the ſquares of the radii or axes.

Remark.

When pieces of artillery are loaded with charges proportional to the weights of their ſhots, the axes of the charges are proportional to their radii; and as they are equally preſſed by the elaſtic force of powder, as far as the charge reaches, their outward ſurface ſhould be ſo far parallel to their inner one, and the thickneſs of the metal made proportional to the radii of their baſes; or becauſe the diameters of the bores are proportional to the diameters of the ſhots, and from thence to the mouth, the outward figure ſhould be that deſcribed by the rotation of a cubic hyperbola about one of its aſſymtotes, which is placed in the axis of the bore: this appears from what has been ſaid in Cor. I. after Theor. IV. But becauſe of the action of the ſhot againſt the inſide of the piece, the thickneſs of metal muſt be ſomewhat more towards the muzzle than what this figure makes it.

Before the foregoing Theory can be applied to any particular example, it is neceſſary to find the ratio be-

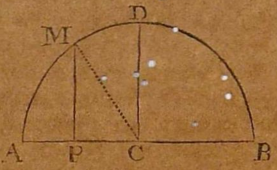
tween the preſſure of the atmoſphere and the elaſtic force of powder, which is very difficult, becauſe authors diſagree very much in their experiments on that head.

For Mr. *Robins* ſays, that the air contained in powder is but 244 times denſer than that we breathe; and that its elaſticity cannot be increaſed above five times by the heat of the exploſion; and from thence he concludes, that the elaſtic force of fired powder is about 1000 times greater than the preſſure of the atmoſphere. The late Mr. *Haukſbee* aſſured me, that he found, by ſeveral experiments, the flame of powder to occupy about 5000 times the ſpace of the powder unfired. Mr. *Belidor* ſays, that, by ſome experiments he made, he found that ſpace to be about 4000 times increaſed, and that the ſame thing had been found by Mr. *Amonton*. Mr. *Bigot de Morogues* ſays, in page 65, that he found that ſpace to be from 4 to 4500 times; and laſtly, *Daniel Bernoullie* found it to be from 4 to 6000 *.

It is certain that theſe experiments are attended with great difficulties, on account of the quickneſs with which the powder fires, and the flame diſappears. Another difficulty ariſes from the inequality of the preſſure of the atmoſphere, as well as from the different ſtrength of powder; and therefore it is impoſſible to arrive at any tolerable degree of exactneſs, notwithſtanding all the precautions that can poſſibly be taken in making the experiments: ſo all that can be expected will be to take ſuch a number as agrees neareſt with the experiments made on the velocities of ſhots, which is that of Mr. *Belidor*'s, as being a mean between the greateſt and leaſt of theſe ſeveral experiments.

* Mr. *Boyle* ſays, that the greateſt denſity of air is to the greateſt rarefaction, as unity to 520,000.

THEOREM V.



The force of an elastic fluid against any part of a spheric surface described by the arc DM *about the radius* CD *as an axis, perpendicular to the diameter* AB, *is to the absolute force, as the solid described by the segment* PMDC *terminated by the sine* PM *of that arc, is to the cylinder of the same base and altitude; and the force against the semi-sphere is to the total force, as the semi-sphere to the circumscribed cylinder.*

Draw the radius CM; then, by the nature of fluids, the surface is pressed in a direction perpendicular to every point; whence the absolute force in the direction CM is to the force impressed at the point M, in the direction PM, as CM is to CP; and as this happens in respect to every point in the arc MD, the force impressed on the arc MD, will be to the absolute force as the area PMDC is to the rectangle made by CP and CD: consequently the force against the surface described by the arc MD about the axis CD, is to the absolute force as the solid described by the segment PMDC in that rotation to the cylinder, described by the rectangle PC and CD; and the force against the semi-sphere is to the absolute force, as the semi-spehre is to its circumscribed cylinder.

Mr. *Robins* and Mr. *Morogues* have supposed, that the force against the semi-sphere was equal to that against the circle AB of the base: but they did not consider, that the directions of the forces against the different parts of the sphere were oblique to the direction CD, in which the sphere is supposed to move; and therefore the total force must be less than the absolute force.

This

This Theorem agrees exactly with Sir *Isaac Newton*'s prop. 35, book ii.

Cor. I.

Since the sphere is the two thirds of its circumscribed cylinder, it follows that the ball is acted upon by the two thirds of the absolute force of the powder.

Example I.

If we suppose C P to be a third part of the radius C A, it will be found by geometry that the cylinder, whose radius of the base is C P, and altitude C D, is to the solid described by the space C P M D about the axis C D; or the total force of the powder is to that part which acts upon the surface described by the arc M D, as 900 to 875: and since the semi-sphere is acted upon by the two thirds of the total force of the powder, and if the quantity be the same in both causes, the force of explosion upon the sphere will be to the part which acts upon the surface described by M D, as 600 to 875; which shews that the force against the surface is only 25 parts less than the absolute force 900: whereas the force against the semi-sphere is but 600, the two thirds of the absolute force 900.

Example II.

If C P be one half of the radius C A, then it will be found in the same manner as before, that the circumscribed cylinder is to the solid described by the space C P M D; or the total force of the powder is to the part acting upon the surface described by the arc M D, as 900 to 841; and the force acting upon the sphere acting upon this solid, as 600 to 841.

Cor. II.

Hence it is manifest that chambers, whose diameters are but one third of the diameter of the bore, are more advantageous than those whose diameters are one half, as they are made at present in our mortars; and if they were still less they would be better; which however may have its limits. This agrees exactly with several experiments made for that purpose: for Mr. *Hawksbee* tried several times a little mortar, which had three shifting chambers of the same capacity, and always found that the chambers which were narrowest carried the shell farthest.

As the first part of artillery was printed before the 18 brass pounders have been proved, and the general construction of these pieces appears to be properly adapted to brass guns for the land service, I shall insert it here, in order to shew how much the metal might be diminished.

General construction of brass cannon for the land service.

Let the length A B, see plate I, be 21 diameters of its shot, the thickness of the metal at the breech and vent 18.5 parts, and at the mouth 9; the rest of the construction may be the same as that given in page 46.

Weight

Weight and dimensions of brass guns for land service.

Calib.	Length.	Weight.
6	6 : 1	8 : 0 : 4
9	7 : 0	12 : 0 : 6
12	7 : 8	16 : 0 : 8
18	9 : 0	24 : 0 : 12
24	9 : 8	32 : 0 : 16
32	9 : 8	42 : 0 : 20
42	9 : 8	52 : 0 : 24

It must be observed, that we made the lengths of the 24, 32, and 42 pounders the same, being sufficient for battering pieces, and reduces the weight of the two last considerably; that these pieces are sufficiently strong appears from the old iron 32 and 42 pounders cast in king *Charles* the second's time, which weighed no more. But it must be remembered, that the charges of these pieces should never exceed one third of their shot's weight, because that charge has been found sufficient by experiments in all battering pieces.

Iron Field Pieces.

Calib.	Length.	Weight.
3	3 : 3	2 : 1 : 0
6	4 : 1	4 : 2 : 0
9	4 : 8	6 : 3 : 0
12	5 : 1	9 : 0 : 0
18	5 : 10	13 : 2 : 0
24	6 : 5	18 : 2 : 0

We have inserted this table of the dimensions of iron field pieces, in order to shew how they may be constructed, in case it should be thought proper to make trial of their strength. Their length is 14 diameters of the shot, the thickness of metal at the breech and vent 18 parts, and 9 at the mouth; the rest of the construction is the same as that of the light brass field pieces.

The proof of these pieces should be made with one half of the shot's weight of powder,

powder, and their charge in ſervice one fourth, which is the ſame as thoſe of braſs.

If theſe pieces are caſt from good virgin ore by a ſkilful founder, ſuch as the *Carron* company, and ſome others, without mixing any pig iron, there cannot be the leaſt doubt but they will be as uſeful, and laſt longer than the light braſs; becauſe their vents ſcarcely ever ſpoil, and the pieces never bend at the neck.

The reader may perhaps be glad to know the greateſt velocities that ſhot can have, and their greateſt ranges, which often have been ſought for by moſt artilleriſts, but they could never agree; for which reaſon we ſhall inſert them in the following table.

The firſt column contains the weight of the ſhot, the ſecond the number of feet moved over uniformly, in a ſecond by the greateſt velocity; and the third the greateſt random ranges which theſe ſhots can poſſibly have, let the charges be ever ſo great.

Shot	Velocities.	Ranges.
3	615.7	2326
6	691.3	2932
9	739.0	3352
12	775.3	3688
18	826.5	4191
24	866.8	4600
32	912.9	5113
42	955.5	5602
48	976.4	5849

This ſhews that ſmall calibers can never go ſo far as greater, and contradicts the common practice of making ſmall calibers longer in proportion, in order to go farther.

A ten inch ſhell may go to 5384 yards at an elevation of 45 degrees, and a thirteen to 7041 yards at the ſame degree of elevation; which is upwards of four miles. Again, the greateſt velocity a leaden bullet of three quarters of an inch diameter can poſſibly have, is at the rate of 395 feet a ſecond, when uniformly continued.

The

The demonſtration of theſe velocities and ranges is given in the appendix. Mr. *Robins* thinks to prove, in his ſeventh problem, that the velocity of the foregoing leaden bullet is 1668 feet in a ſecond, which is more than four times greater than that above; and what is more extraordinary, he pretends to have found the ſame velocity by experiments. As he ſeems to build his theory upon Sir *Iſaac Newton's* principles, had he read the 40th propoſition, book ii. he muſt have been convinced of his miſtake; and from over rating the velocities, the reſiſtance of bodies moving in the air is, according to his computation, above twenty-four times too great in a 24 pounder.

Height. Yds.	Diſtance. Yards	Miles	Height. Yd.	Diſtance. Yards	Miles
1	3735	2. 12	26	19048	10. 82
2	5278	3. 00	27	19410	11. 03
3	6470	3. 67	28	19767	11. 23
4	7470	4. 24	29	20107	11. 42
5	8353	4. 74	30	20460	11. 62
6	9150	5. 20	31	20800	11. 82
7	9863	5. 60	32	21133	12. 00
8	10566	6. 00	33	21450	12. 20
9	11206	6. 36	34	21780	12. 38
10	11800	6. 70	35	22100	12. 55
11	12390	7. 04	36	22413	12. 73
12	12940	7. 35	37	22720	12. 91
13	13468	7. 65	38	22895	12. 97
14	13977	7. 94	39	23329	13. 20
15	14468	8. 22	40	23634	13. 40
16	14942	8. 49	41	23919	13. 59
17	15402	8. 75	42	24209	13. 75
18	15850	9. 00	43	24500	13. 92
19	16285	9. 25	44	24780	14. 08
20	16706	9. 49	45	25059	14. 24
21	17118	9. 72	46	25335	14. 40
22	17521	9. 95	47	25610	14. 55
23	17915	10. 18	48	25880	14. 70
24	18300	10. 40	49	26148	14. 85
25	18678	10. 61	50	26414	15. 00

As

As the diſtance a ſhip may be ſeen at ſea is eſteemed uſeful, we have given them from one yard high to 50, from the ſurface of the ſea, and the reſpective diſtances in yards and miles: they are deduced from the roundneſs of the ſeas ſurface, according to the prob. in art. 411, of our treatiſe of mathematics: the mean diameter of the earth being 6548856 *French* toiſes, according to our determination; which being reduced into *Engliſh* yards, gives 7.1447018 for its logarithm; to which adding continually the logarithm of the height, gives the logarithm of the ſquare of the diſtances in yards; and the diſtances in yards being divided by 1760, the number of yards in a mile, gives the number of miles which theſe diſtances contain.

The navigator may always know the height he is from the ſurface of the ſea, when he obſerves the hull of another ſhip, at the water edge, then he has the diſtance marked in the table againſt the height from which he obſerves; but if any part of the ſhip he obſerves is hid by the ſurface of the water, he muſt give a gueſs how high the part hid is; then if he adds the diſtance againſt that height expreſſed in yards, to that againſt the height he ſees, the ſame will be the true diſtance to the ſhip.

Example. Suppoſe he obſerves a ſhip from a height of 15 yards, and the part of the ſhip hid is 5 yards; then the diſtance 6470 againſt 5 yards, added to the diſtance 14468 againſt 15 yards, gives 20938 yards or 12 miles nearly for the diſtance required.

We have not conſidered the refraction of the air, by which the ſhip may be ſeen a little farther than what is marked in the table. But if the ſhip is within the horizon, and the height of the part ſeen between the ſurface of the water and the horizontal line, then the diſtance anſwering to this height, ſubtracted from the firſt, gives that between the two ſhips.

ARTILLERY.

ARTILLERY.

PART I.

Weights *and* Measures.

TO proceed with order in the enſuing work, it is proper to mention the neceſſary weights and meaſures uſed in Artillery, for the better underſtanding the uſe and conſtruction of the tables.

An inch is the leaſt common meaſure; 12 inches make a foot, 3 feet a yard, a pole is 16.5 feet, a furlong 40 yards, and a mile 1760 yards. Theſe meaſures are alſo ſub-divided into 10, 100, and 1000 parts.

Avoirdupois weight is uſed in Artillery, and in all heavy commodities; a drachm is the leaſt weight, 16 of which make an ounce, 16 ounces a pound, 14 pounds a ſtone, 112 pounds a hundred weight, 20 hundreds a ton.

As *French* weights and meaſures are proper to be underſtood in Artillery, we ſhall give the proportion between ours and theirs. The gentlemen of the Royal Society in *London*, in conjunction with thoſe of the Royal Academy of Sciences at *Paris*, are ſaid to have, with

great

great accuracy, compared our weights and meaſures with thoſe of *France*; the reſult of which is,

The *Engliſh* foot to the *French* royal, as 107 to 114. The *Engliſh* pound avoirdupois to the *French* pound marc, as 63 to 68. Whence 100 *French* pounds make very near 108; and therefore their hundred-weight is to ours, as 108 to 112; that is, as 27 to 28, according to this proportion.

The proportion of the *French* and *Engliſh* foot is nearly exact; for I tried two *French* ſectors, the one made by *le Maire* ſeemed to be exactly divided, and I found that three *French* inches make 3.2 of ours; ſo that the *French* foot is to ours as 32 to 30, which is near 114 to 107; ſince if 114 be multiplied by 15, the product will be 1710; and 107 multiplied by 16, gives 1712; which exceeds the former by 2 only.

But the proportion of the *French* and our weights is by no means right, as will appear hereafter, when we give tables of ſhots. It is hard to judge how ſuch a miſtake could happen, unleſs the weights they compared were not thoſe uſed in the Artillery there and here.

Before we proceed any farther, it will be neceſſary to premiſe ſome geometrical propoſitions, which ought to be known, in order to underſtand ſeveral parts of this work.

I. The diameter of the circle is to its circumference, as 113 is to 355 nearly.

II. The ſquare of the diameter is to the area of the circle, as 452 to 355.

III. The cube of the diameter is to the ſolid content of a ſphere, as 678 to 355.

IV. The cubes of the axes are to the ſolid contents of equialtitude cylinders, as 452 to 355.

V. The ſolid content of a ſphere is to the circumſcribed cylinder, as 2 to 3. Theſe propoſitions are demonſtrated in the Ninth Section of my Elements of Mathematics.

The

The following table contains the weight of a cubic foot, expreſſed in ounces, of the ſeveral ſubſtances ſpecified, which I have for the moſt part taken from Mr. *Cotes*'s hydroſtatic lectures. Thoſe of gun metal have been computed from their mixture, and the caſt iron from the 9 pound ball, whoſe diameter is four inches, exceedingly near, according to Sir *Jonas Moor*.

Specific gravities of bodies.

Copper	9000	Steel	7645
Tin	7320	Marble	2700
Gun metal	8784	Dry oak	925
Caſt braſs	8000	Dry aſh	800
Lead	11325	Dry maple	755
Iron	7645	Dry elm	600
Caſt iron	7425	Dry fir	550
Shells	4892	Powder	880

For his father weighing ſeveral iron balls with a curious ſcale, found one nearly round, whoſe diameter was 6.63 inches, and weighed 41 pounds; from thence the diameter of a 9 pound ball is found to be 3.9995 inches, which being ſo very near 4 inches, by taking it as ſuch, no ſenſible error can happen in computation.

Having the weight of a cubic foot of theſe bodies, that of any parts may be found by proportion; and on the contrary, the weight of any part of a body being given, its ſpecific gravity, or the weight of a cubic foot, may be found. Thus a cubic foot, or 1728 cubic inches of gun metal, weigh 8784 ounces, or 549 pounds: then dividing 1728 by 9, we get 192 cubic inches; and dividing 549 by 9, we get 61 pounds. Hence 192 cubic inches of gun metal weigh 61 pounds.

Again: 1728 cubic inches of caſt iron weighing 7425 ounces, or 464 pounds and an ounce, which we ſhall neglect; then 1728 divided by 16, gives 108, and 464 divided by 116, gives 29. Hence 108 cubic inches of

caſt iron weigh 29 pounds. Theſe two examples will be uſeful hereafter in finding the weight of guns.

A ſhell, whoſe diameter is 12¾, weighs 192 pounds when loaded, as will be ſhewn; and 355 is to 678, as the content or weight 192, is to the content or weight of the cube 366.69 made by its diameter: but the cube 2072.67 of 12¾, is to the cube 1728 of 12, as the weight 366.69 is to the weight 4892 of a cubic foot, or the ſpecific gravity of ſhells.

Again: a cylinder of powder, whoſe axis and diameter are each 3.42 inches, contains one pound, or 16 ounces, as will be ſhewn hereafter; and 355 is to 452, as the weight 16 ounces of the cylinder is to the weight 20.372 ounces of the cube made by its axis: but the cube 40 of 3.42 is to the cube 1728 of 12, as the weight 20.372 is to the weight 880 ounces of a cubic foot, or the ſpecific gravity of ordnance powder.

EXAMPLE I.

To find the diameter of an iron ball, whoſe weight is given, ſuppoſing that of a 9 pound is 4 inches. Say, the cube root, 2.08, of 9 pounds is to 4 inches, as the cube root of the given weight is to the diameter ſought; or if 4 be divided by 2.08, the cube root of 9, the quotient 1.923 will be the diameter of a one pound ball; which being continually multiplied by the cube root of the given weight, gives the diameter required.

This may be done in a ſhorter manner by making uſe of logarithms; for if the logarithm .2839793 of 1.923 be conſtantly added to the third part of the logarithm of the weight, the ſum will be the logarithm of the diameter. Suppoſe a ball to weigh 24 pounds, add the given logarithm .2839793, to the third part .4600704 of the logarithm 1.3802112 of 24, the ſum .7440494 will be the logarithm of the diameter of a ball weighing 24 pounds, which therefore is 5.5468 inches.

If

If the weight be expreſſed by a fraction, the rule is ſtill the ſame; for inſtance, the diameter of a pound and a half ball, or of $\frac{3}{2}$, is found, by adding the logarithm .2839793, found above, to .0586971, one third of the logarithm of $\frac{3}{2}$; the ſum .3426764, will be the logarithm of the diameter required, which therefore is 2.2013 inches.

The diameter of an ounce ball is found, by ſubtracting .4013733, one third of the logarithm of 16, from the logarithm .2839793, of one pound; as this logarithm is leſs than the other, an unit muſt be added to it; then the difference .882606, will be the logarithm of the ball's diameter, which weighs an ounce. This logarithm being continually added to the third part of the logarithm of the weight, expreſſed in ounces, and an unit being taken from the ſum, the remainder will be the logarithm of the diameter: thus, let the ball weigh eight ounces, add .3010300, the third part of the logarithm of 8, to the logarithm .882606 of one ounce; the ſum .18363, after having ſubtracted unity, will be that of the diameter, which is 1.526 inches.

As the diameter of the bore, or the caliber of the piece, is made one twentieth part larger than that of the ſhot, according to the preſent practice, we have computed the following

Diameters of the shots and calibers of English *guns.*

lb.	0	1	2	3	4	5	6	7	8	9	
0	0	1.923	2.423	2.775	3.053	3.288	3.498	3.679	3.846	4.000	Diam.
	0	2.019	2.544	2.913	3.204	3.568	3.668	3.861	4.038	4.200	Calib.
1	4.143	4.277	4.403	4.522	4.635	4.743	4.846	4.945	5.040	5.131	Diam.
	4.349	4.490	4.623	4.748	4.866	4.981	5.088	5.192	5.292	5.386	Calib.
2	5.220	5.305	5.388	5.4[illegible]9	5.547	5.623	5.697	5.769	5.839	5.908	Diam.
	5.480	5.570	5.661	5.742	5.824	5.893	5.982	6.057	6.129	6.203	Calib.
3	5.975	6.041	6.105	6.168	6.230	6.290	6.350	6.408	6.465	6.521	Diam.
	6.273	6.343	6.410	6.475	6.541	6.604	6.666	6.707	6.788	6.846	Calib.
4	6.576	6.631	6.684	6.737	6.789	6.640	6.890	6.940	6.989	7.037	Diam.
	6.904	6.962	7.018	7.076	7.128	7.182	7.234	7.287	7.338	7.383	Calib.

The

The numbers in the firſt horizontal line are units, and thoſe in the firſt vertical column the tens: the other numbers under the one, and oppoſite to the others, are the reſpective diameters of ſhot and calibers. Thus to find the diameter of the ſhot, and the caliber of a 24 pounder, look for the number 2 at the ſide, and for 4 at top; then the number 5.547 under 4, and oppoſite to 2, will be the diameter of the ſhot in inches and decimals, and the number 5.824, under the firſt, the caliber of the 24 pounder. Again, to find the diameter of the ſhot, and the caliber of a 36 pounder; look for 3 at the ſide, and 6 at the top, then the number 6.350, under 6, and oppoſite to 3, will be the diameter of the ſhot, and the number 6.666 under it, the caliber of the 36 pounder. In the ſame manner may be found the diameter of the ſhot and the caliber of any gun, under a 60 pounder: thoſe above 48 are not uſed.

Diameters of the shots and bores of French *guns by inches and decimals of their measure.*

	0		1		2		3		4	
	Diameter.	Caliber.	Diameter.	Caliber.	Diameter.	Caliber.	Diameter.	Caliber.	Diameter.	Caliber.
0	0	0	4.072	4.222	5.130	5.320	5.872	6.089	6.463	6.702
1	1.889	1.950	4.203	4.390	5.214	5.407	5.937	6.157	6.517	6.758
2	2.381	2.469	4.327	4.487	5.295	5.491	6.000	6.222	6.569	6.812
3	2.726	2.827	4.444	4.608	5.375	5.584	6.062	6.288	6.621	6.806
4	3.000	3.111	4.555	4.723	5.451	5.653	6.122	6.349	6.672	6.918
5	3.253	3.351	4.661	4.833	5.526	5.730	6.182	6.411	6.722	6.971
6	3.434	3.561	4.762	4.938	5.599	5.806	6.237	6.468	6.771	7.022
7	3.615	3.749	4.859	5.039	5.670	5.880	6.297	6.530	6.820	7.072
8	3.790	3.920	4.953	5.134	5.739	5.951	6.354	6.589	6.868	7.122
9	3.931	4.076	5.043	5.229	5.847	6.061	6.409	6.646	6.916	7.172

This

This table is conſtructed upon the ſuppoſition that the diameter of a four pound ball is three *French* inches, according to their authors ; and from thence, the difference between the logarithm of three inches, and one third of the logarithm of four pounds, gives the logarithm .276,347 of the diameter of a one pound ball, which being continually added to one third of the number of pounds of the ball, the ſum will be the logarithm of the diameter of that ball in inches and decimals. The windage of the *French* guns is but one twenty-ſeventh part of the ball's diameter : which, therefore, being added to the diameter, gives that of the caliber. Mr. *Saint Remy* gives a table of theſe diameters in page 136, vol. i. new edit. in inches and duodecimals, without mentioning how it was conſtructed. In page 82, he ſays, that *Butterfield* has computed it, and that it is very exact. *Butterfield* was an *Engliſh* mathematical-inſtrument-maker eſtabliſhed at *Paris*.

This table agrees nearly with that given by *Saint Remy*, p. 136, as appears from the following numbers, where lines and points are reduced into decimals of an inch.

The firſt column contains the weights of the ſhot, the ſecond their diameters in inches and decimals according to *Saint Remy*, and in the third the ſame diameters according to our tables. Hence, our diameters are greater as far as a thirty-ſix pound ſhot, and leſs above it. Therefore the *French* table has not been conſtructed from the rule that the weights of ſhots are as the cubes of their diameters, unleſs ſome errors have been committed in their computations.

lb.		
24	5.444	5.451
36	6.229	6.237
39	6.417	6.409
41	6.518	6.517
46	6.776	6.771

The following table has been computed upon the ſuppoſition, that the *French* foot is to the *Engliſh* as 114 is to 107, as we have ſhewn in page 2 ; and from thence, the logarithm of the diameter of a *French* pound is .3039558, expreſſed in *Engliſh* inches and decimals.

As to the reft of the diameters they are found in the fame manner as before.

Diameters of the fhots and bores of French *guns in* Englifh *inches.*

		0	1	2	3	4	5	6	7	8	9	
0		0	2. 013	2. 537	2. 904	3. 196	3. 443	3. 659	3. 852	4. 027	4. 188	Diameter.
		0	2. 088	2. 631	3. 011	3. 315	3. 570	3. 794	3. 994	4. 180	4. 343	Caliber.
1		4. 338	4. 478	4. 610	4. 734	4. 853	4. 966	5. 074	5. 177	5. 277	5. 373	Diameter.
		4. 499	4. 554	4. 781	4. 910	5. 032	5. 150	5. 262	5. 365	5. 472	5. 571	Caliber.
2		5. 466	5. 555	5. 642	5. 726	5. 808	5. 887	5. 965	6. 041	6. 114	6. 186	Diameter.
		5. 668	5. 761	5. 851	5. 938	6. 023	6. 105	6. 186	6. 264	6. 341	6. 415	Caliber.
3		6. 256	6. 325	6. 393	6. 458	6. 523	6. 586	6. 648	6. 709	6. 769	6. 828	Diameter.
		6. 488	6. 559	6. 629	6. 698	6. 765	6. 830	6. 895	6. 958	7. 020	7. 086	Caliber.
4		6. 886	6. 943	6. 999	7. 054	7. 108	7. 162	7. 245	7. 266	7. 318	7. 368	Diameter.
		7. 141	7. 200	7. 258	7. 315	7. 372	7. 427	7. 513	7. 536	7. 589	7. 641	Caliber.

This

This table ſerves to compare the *French* calibers to ours: for example, the diameter 5.808 of a 24 pound ball is ſomething more than 5.769, that of our 27. That 6.393, of their 32, nearly equal to 6.408, that of our 37. That 6.648 of their 36, nearly equal to 6.684 of our 42.

The diameter of a *French* 9 pound ſhot is 4.188 inches of our meaſure, and its cube 73.453; and as the diameter of our 9 pounder is 4 inches, and its cube 64; therefore the *French* weight is to ours as 73.453 is to 64, or as 70 to 61 nearly: which differs greatly from the ratio mentioned before. Therefore 100 *French* pounds make 114¾ pounds, and not 108, as the former proportion gives.

The proof that this ratio is the neareſt that can be given by two figures, we ſhall ſuppoſe, with Sir *Jonas Moor*, that the diameter of a 9 pound iron ſhot is 3.9995 inches; then as 114 is to 107, as 3.9995 is to 3.7593 *French* inches, whoſe cube is 52.899, and 70 is to 61 as 9 to 7.8428 pounds *French* weight. Therefore the cube 52.899 is to the cube 27 of 3, as the weight 7.8428 is to the weight 4.0004 pounds of the ſhot, whoſe diameter is 3 *French* inches, which agrees nearly with the ſuppoſition of the *French*: but if the ratio 68 to 63 be ſuppoſed, a 9 pounder *Engliſh* weighs 8.3382; then by proportion the weight of a ſhot, whoſe diameter is 3 *French* inches, will be 4.2558 pounds, or above a quarter more than 4 pounds; which is certainly more than it is poſſible not to perceive.

Iron

Iron grape shot from 1 to 39 ounces.

Nº	0	1	2	3	4	5	6	7	8	9
0	0	.763	.9615	1.103	1.209	1.305	1.387	1.450	1.526	1.587
1	1.644	1.697	1.747	1.794	1.839	1.882	1.923	1.962	2.000	2.036
2	2.072	2.106	2.138	2.170	2.201	2.231	2.261	2.286	2.318	2.345
3	2.371	2.397	2.423	2.448	2.472	2.496	2.501	2.543	2.566	2.588

Whence the diameter of any bullet is found, by dividing 1.6706 inches by the cube root of the number, which ſhews how many of them make a pound; or this may be done in a ſhorter manner. From the logarithm .2228756 of 1.6706 ſubtract continually the third part of the logarithm of the number of bullets in the pound, and the difference will be the logarithm of the diameter required.

Thus the diameter of a bullet, whereof 12 weigh a pound, will be found by ſubtracting .3597270, a third part of the logarithm of 12, from the given logarithm .2228756, or, when this logarithm is leſs than the former, an unit muſt be added, ſo as to have 1.2228756, and the difference .8631486 will be the logarithm of the diameter ſought; which is .7297 inches; obſerving that the number found will always be a decimal, when the logarithm which is to be ſubtracted is greater than that of one pound; becauſe the diviſor is greater than the dividend in this caſe.

From the ſpecific gravity of lead, the diameter of any bullet may be found from its given weight. For ſince a cubic foot weighs 11325 ounces by our table, and 678 is to 355 as the cube 1728 of a foot, or 12 inches, is the content of the ſphere, which therefore is 5929.7 ounces; and ſince ſpheres are as the cubes of their diameters, the weight 5929.7 is to 16 ounces, or one pound, as the cube 1.728 is to the cube of the diameter of a ſphere which weighs a pound; which cube therefore is 4.66263, and its root 1.6706 inches, the diameter ſought.

Sir *Jonas Moor* makes this diameter 1.69 inches: though he was very curious in his experiments, yet as the ſpecific gravities have likewiſe been determined by *Cotes* and ſeveral eminent men, it would be a preſumption in me to determine which of the two diameters is the moſt accurate; for which reaſon we ſhall give two tables, one of each of theſe ſuppoſitions, leaving the choice to the impartial reader.

Diameters

Diameters of leaden bullets from 1 *to* 39 *in the pound, according to the author.*

	0	1	2	3	4	5	6	7	8	9
0	0	1.671	1.326	1.158	1.05	.977	.919	.873	.835	.803
1	.715	.751	.730	.711	.693	.677	.663	.650	.637	.626
2	.615	.605	.596	.587	.579	.571	.564	.557	.550	.544
3	.538	.532	.526	.521	.517	.511	.506	.501	.497	.493

Diameters of leaden bullets from 1 *to* 39 *in the pound, according Sir* Jonas Moor.

	0	1	2	3	4	5	6	7	8	9
0	0	1.690	1.341	1.172	1.064	0.988	0.930	0.883	0.845	0.812
1	0.784	0.760	0.738	0.719	0.701	0.685	0.671	0.657	0.645	0.633
2	0.623	0.612	0.603	0.594	0.586	0.578	0.570	0.563	0.556	0.550
3	0.544	0.537	0.532	0.527	0.521	0.517	0.512	0.507	0.503	0.498

The diameter of the muſket bores differ not above one fiftieth part from that of the bullet; for if the ſhot but juſt rolls into the barrel it is ſufficient. The government allows 11 bullets in the pound, for the proof of muſkets, and 14 in the pound, or 29 in two pounds, for ſervice: 17 for the proof of carabins, and 20 for ſervice; and 28 in the pound for the proof of piſtols, and 34 for ſervice.

As powder meaſures are uſeful in artillery, being more handy than weights, ſaving time, and are neceſſary in ricochet firing, we ſhall inſert here ſome experiments I made upon that ſubject in 1753, at the royal academy of artillery.

I. A cy-

I. A cylinder, whose axis and diameter were two inches each, contained 3 ounces and 3 grains, or 51 grains; and as similar cylinders are as the cubes of their axis; if we say 51 grains are to 256 grains, or one pound, as the cube 8 of 2 inches is to the cube 40.156 of the diameter of a like cylinder holding one pound.

II. A cylinder, whose axis and diameter were 4 inches each, held 25 ounces and 10.5 grains, or 410.5 grains; whence 410.5 grains are to 256 grains, as the cube 64 of 4 inches is to 39.912, the cube of the axis of a cylinder holding one pound.

III. A cylinder, whose diameter and axis were 6 inches each, held 5 pounds 6 ounces and 6 grains, or 1382 grains. Hence 1382 : 256 : : 216 : 40.01 for the cube required.

IV. A two-inch cube held 4 ounces and 1 grain, or 65 grains; and as 452 is to 355, so is the cube 8 of the axis to the content of the cylinder, which therefore is 51.05. Hence 65 : 256 : : 8 : 40 : 117, the cube of the axis.

V. A six-inch cube held 6 pounds 13 ounces and 13 grains, or 1757 grains; so then 452 : 355 : : 1757 : 1379.944, or 1380, the content of the cylinder; and if 1380 : 256 : : 216 : 40.07, this fourth term will be the cube of the axis required. Hence a medium of these five experiments gives 40.053 cubic inches, whose cube root 3.42 will be the diameter of a cylinder holding a pound of powder.

From hence we may deduce the specific gravity of powder, which is no more than the content of a cubic foot expressed in ounces. Now since 355 is to 452, as the content 16 ounces of the cylinder is to 20.372, the content of the cube of its axis, and the cube 40 of the axis is to the cube 1728 of 12 inches, or a foot, as 20.372 ounces to 880 ounces contained in a cubic foot of powder.

Sir *Jonas Moor* found by several experiments the diameter of a cylinder holding a pound of powder to be 3.165 inches.

Dia-

Diameters and heights of cylindric powder measures from 1 to 39 ounces, according to the author.

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.357	1.710	1.957	2.154	2.321	2.467	2.596	2.714	2.830
1	2.924	2.963	3.107	3.191	3.271	3.347	3.420	3.490	3.557	3.622
2	3.684	3.744	3.803	3.859	3.915	3.968	4.021	4.072	4.121	4.170
3	4.217	4.263	4.309	4.353	4.397	4.439	4.481	4.523	4.563	4.603

The logarithm of an ounce is .1326467; the other numbers are found, by adding one third of the logarithm of the number of ounces. Thus the number of 8 ounces is found by adding .3010300, one third of the logarithm of 8 to that of one ounce, which gives .4336767 for the logarithm of the number sought; which therefore is 2.714.

Diameters and heights of cylindric powder measures from 1 to 39 pounds, according to the author.

℔	0	1	2	3	4	5	6	7	8	9
0	0	3.420	4.309	4.932	5.429	5.848	6.214	6.541	6.824	7.114
1	7.368	7.606	7.830	8.041	8.243	8.434	8.618	8.794	8.963	9.126
2	9.283	9.435	9.583	9.726	9.865	10.00	10.13	10.26	10.38	10.51
3	10.63	10.74	10.86	10.97	11.08	11.16	11.29	11.45	11.50	11.60

Diameters of cylindric powder measures, when the diameter is to the axis as 2 to 3, according to the author.

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.181	1.491	1.710	1.880	2.027	2.155	2.268	2.371	2.472
1	2.554	2.588	2.714	2.788	2.857	2.924	2.988	3.049	3.164	3.164
2	3.218	3.271	3.322	3.371	3.420	3.466	3.513	3.557	3.600	3.643
3	3.684	3.724	3.764	3.802	3.841	3.878	3.915	3.951	3.986	4.021

lb.	0	1	2	3	4	5	6	7	8	9
0	0	2.988	3.764	4.308	4.743	5.109	5.428	5.714	5.961	6.215
1	6.436	6.644	6.840	7.024	7.201	7.368	7 529	7.682	7.830	7.972
2	8.109	8.242	8.372	8.496	3.618	8.736	8.849	8.963	9.068	9.181
3	9.286	9.382	9.496	9.583	9.679	9.769	9.863	10.00	10.05	10.13

Theſe diameters are found, if thoſe of the former tables be divided by 1.1447, the cube root of $\frac{3}{2}$.

As I look upon theſe experiments to have been made with great accuracy, this difference can proceed from no other cauſe, than that the grain of the powder was ſomething finer in his time than at preſent. The changing the ſize of the grains, is attended with many inconveniencies without the leaſt advantage; for the powder meaſures made at one time are either larger or leſs than what they ſhould be at another, whereby great miſtakes are made in loading of pieces. Sometimes more, and other times leſs powder is uſed than intended; and to change them continually, is attended with expences,

pences, and cannot always be done abroad, where they have no conveniency to do it: ſuch miſtakes were made at *Minorca* ſome years ago, where the powder meaſure held 35 pounds inſtead of 30; and at the end of the ſeaſon, the officer could not account for the ſpending ſo much more powder than he intended, till he found the miſtake by examining the meaſure.

When the grains are made as large as we do at preſent, it happens that ſome of them are much ſmaller than others, and the ſmall take fire ſooner than the reſt, by which the force of ſome is partly expended before the reſt is fired, and conſequently the total force is not ſo great as it would be, if the grains were nearly of the ſame ſize.

It has been imagined by ſome, that the large grained powder is ſtronger than the ſmall: but Captain *Deſagúliers* made ſome experiments with grained and mealed powder; both which carried the ſhot the ſame diſtance. It may be preſumed, that powder was not grained at its firſt diſcovery, but in courſe of time experience ſhewed, that it kept longer in grains than otherwiſe; for which reaſon this cuſtom is followed by all nations, and is undoubtedly the beſt.

Diameters and heights of cylindric powder meaſures, holding from 1 *ounce to* 19, *according to Sir* Jonas Moor.

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.257	1.583	1.811	1.994	2.148	2.282	2.403	2.512	2.613
1	2.706	2.793	2.876	2.953	3.027	3.098	3.165	3.230	3.292	3.352

These diameters are in inches and decimals.

Diameters

Diameters and heights of cylindric powder measures, holding from 1 to 19 pounds.

lb.	0	1	2	3	4	5	6	7	8	9
0	0	3.165	3.988	4.565	5.024	5.412	5.751	6.054	6.330	6.583
1	6.890	7.039	7.245	7.442	7.628	7.805	7.975	8.138	8.295	8.391

This laſt table is conſtructed in this manner; multiply continually the cube 31.705, of 3.165, by the number expreſſing the weight of powder, and the product will be the cube of the diameter and axis of the cylinder ſought. Or thus, add continually .5003737, the logarithm of 3.165, to the third part of the logarithm of the number ſhewing the weight, then the ſum will be the logarithm of the diameter required.

Thus one third .2006866, of the logarithm of 4, being added to the logarithm .5003737, gives .7010603, for the logarithm of the diameter of a cylinder, holding 4 pounds of powder, which is 5.024 inches.

The diameter of a cylinder, holding an ounce of powder, is found by ſubtracting one third of .4013733, the logarithm of 16, from the logarithm .5003737, then the difference .0990004, will be the logarithm of the diameter required; which being continually added to one third of the logarithm of the given number of ounces, gives the logarithm of the diameter ſought.

As powder meaſures are more convenient, when their axis is longer than their diameters, we ſhall give the

Diameters of cylindric powder measures, when the diameter is to the height, as 2 to 3, according to Sir Jonas Moor.

℥	0	1	2	3	4	5	6	7	8	9
0	0	1.097	1.382	1.582	1.742	1.876	1.994	2.099	2.194	2.282
1	2.364	2.440	2.512	2.580	2.644	2.706	2.765	2.820	2.874	2.926

lb.	0	1	2	3	4	5	6	7	8	9
0	0	2.765	3.483	3.988	4.389	4.728	5.024	5.289	5.530	5.751
1	5.957	6.149	6.330	6.501	6.664	6.819	6.967	7.104	7.241	7.325
[illegible]	7.505	7.628	7.749	7.863	7.975	8.085	8.191	3.204	8.396	8.495

These two last tables are constructed, by multiplying continually the diameter in the two former tables, by the cube root .873 of $\frac{2}{3}$, then the product will give the diameters of cylinders, holding the same quantity of powder, or else by adding —.0586971, the logarithm of .873, or the third part of that of $\frac{2}{3}$, to the logarithm .5003737, found above; then the sum .4416766, being continually added to one third of the logarithm of the number expressing the weight, the sum will be the logarithm of the diameter sought.

For example, to find the measure that shall hold 28 pounds: the logarithm of 28 is 1.4471580, one third of which being added to the given logarithm .4416766, gives .9240626, for the logarithm of the diameter required, which therefore is 8.396 inches.

This rule is proved from the known property in geometry, that equal solids have their bases and altitudes reciprocally proportional. Hence, if a expresses the diameter of the base or altitude, and x the diameter of the

the baſe of the cylinder required; then becauſe the diameter x of the baſe is to its altitude as 2 to 3 by ſuppoſition, the altitude will be $\frac{3}{2}x$; and hence, $a^3 = \frac{3}{2}x^3$, by the condition of the problem, or $\frac{2}{3}a^3 = x^3$; the cube root of which is $a^3\sqrt{\frac{2}{3}} = x$.

In the ſame manner may be found the diameter of a cylinder, which is to its altitude in any other given ratio, ſuch as 1 to 2, or as 3 to 5.

As it is neceſſary that an artillery officer ſhould know how to compute the number of ſhot contained in a ſquare or oblong pile, finiſhed or unfiniſhed, we ſhall give here a method for finding the number of ſhot more general than that in our Elements of Mathematics, page 98, deduced from a moſt compendious principle.

Investigation *of a general rule for finding the ſums of ſeries's.*

If z expreſſes the number of terms of a ſeries, whoſe ſum can be expreſſed by the product of factors that are in an arithmetical progreſſion; to find the z or general term of that ſeries.

N. B. The general term of a ſeries is ſuch an expreſſion compoſed of a variable z and conſtant quantities, that when z is made equal to 0, 1, 2, 3, or 1, 2, 3, 4, it gives the firſt, ſecond, third, fourth term of that ſeries.

It is evident, that by diminiſhing the value of z by the common difference n of the factors, the ſum will be diminiſhed by the laſt term, and the difference between theſe two ſums will be the z or general term required.

Thus if $z.\ z+n.\ z+2n.\ z+3n$, be the ſum of any ſeries, by writing $z-n$ for z, we get $z-n.\ z.\ z+n.\ z+2n$: which ſubſtracted from the firſt, gives $4n.\ z.\ z+n.\ z+2n$, for the general term required.

N. B. The points between the factors ſignify multiplication.

General RULE.

From the ſum of a ſeries, to find its general term; *multiply the ſum by the number of factors and the common difference, and ſtrike out the laſt factor.*

N. B. Whether the ſum is multiplied by a conſtant number, or the factors decreaſe or increaſe, the rule is the ſame.

Thus the ſum az gives a for a general term; $z.\,z+1$ gives $2z$; the ſum $z.\,z-1.\,z-2$ gives $3z.\,z-1$, and $z.\,z+n.\,z+2n.\,z+3n$, gives $4n.\,z.\,z+n.\,z+2n$.

General RULE.

From the general term of a ſeries to find the ſum of any number z of terms.

Increaſe the factors by one more factor, and divide by the number of factors thus increaſed, and by the common difference.

Thus the general term a gives az for the ſum, az gives $\frac{1}{2}az.\,z+1$; $z.\,z+1$ gives $\frac{1}{3}z.\,z+1.\,z+2$, and $z.\,z-n.\,z-2n$, gives $\frac{1}{4n}z.\,z-n.-z-2n.\,z-3n$.

Obſerve, when the firſt value of z is o, the factors muſt be of a decreaſing progreſſion; but if it is any number of an increaſing progreſſion, as examples will ſhew.

EXAMPLE I.

Let the ſeries be any arithmetical progreſſion as a, $a+n$, $a+2n$, $a+3n$, &c. whoſe general term is $a+zn$, when the values of z are o, 1, 2, 3, and the ſum $az+\frac{1}{2}n.\,z-z-1.$ of z terms. If 1, 2, 3, 4; then $a=n=1$, and $\frac{1}{2}z.\,z+1$, the ſum of z terms. If 5, 7, 9, 11, then $a=5$, $n=2$, and $5z+z.\,z-1$ or $z.\,z+4$, the ſum of z terms.

EXAMPLE II.

Let the series be the squares of an arithmetical progression, as aa, $\overline{a+n}|^2$, $\overline{a+2n}|^2$, &c. whose general term is $\overline{a+zn}|^2$ or $aa+2nz+nnzz$, and 0, 1, 2, 3, the values of z: hence the sum of the two first terms is $aaz+nz.\overline{z-1}$, and since $zz=z+z.\overline{z-1}$, whose sum is $\frac{1}{2}z.\overline{z-1}+\frac{1}{3}z.\overline{z-1}.\overline{z-2}$, or $\frac{1}{6}z.\overline{z-1}.\overline{2z-1}$, when reduced under the same denomination.

Therefore $aaz+nz.\overline{z-1}+\frac{1}{6}nnz.\overline{z-1}.\overline{2z-1}$, is the Sum of z terms of that series.

Thus if the series is the squares of the natural numbers 1, 2, 3, 4, then $a=n=1$, and $z+z.\overline{z-1}+\frac{1}{6}z.\overline{z-1}.\overline{2z-1}$, or $\frac{1}{6}z.\overline{z+1}.\overline{2z+1}$, when reduced under the same denomination.

If the series is 1, 9, 25, 49, that is the squares of the numbers 1, 3, 5, 7, 9, then is $a=1$, $n=2$, and $z+2z.\overline{z-1}+\frac{2}{3}z.\overline{z-1}.\overline{2z-1}$, or $\frac{1}{3}z.\overline{2z+1}.\overline{2z-1}$, the sum when reduced. If $z=10$, then will 1330 be the sum of the 10 first terms.

EXAMPLE III.

If ab, $\overline{a+1}.\overline{b+1}$, $\overline{a+2}.\overline{b+2}$, be the series, which is that of the horizontal range of a rectangular pile of shot, whose general term is $\overline{a+z}.\overline{b+z}$, or $ab+\overline{a+b}.z\times zz$, and 0, 1 2, 3, 4, the values of z; the sum is therefore $abz+\overline{a+b}.\frac{1}{2}z.\overline{z-1}+\frac{1}{6}z.\overline{z-1}.\overline{2z-1}$, by examp. II.

This series may be reduced to A. $\overline{2a+z-1}\times\overline{2b+z-1}+\frac{1}{3}\overline{z+1}.\overline{z-1}.x$ by $\frac{1}{4}z$. For $\overline{2a+z-1}$, multiplied by $\overline{2b+z-1}$, gives $4ab+\overline{2a+2b}.\overline{z-1}+\overline{z-1}.\overline{z-1}$, and $\overline{z-1}.\overline{z-1}$ added to $\frac{1}{3}\overline{z+1}.\overline{z-1}$, and the whole divided by 4 gives the first sum.

General RULE *for an incomplete pile.*

To twice the length and breadth of the upper ſurface, add the corner row leſs one.

To the product of theſe two numbers add one third of the product, the corner row leſs one by the corner row more one, and multiply the ſum by one fourth of the corner row.

Thus, if the ſides of the upper ſurface are 20 by 4, and the corner row 6;

Then the ſum of 40 and 5, multiplied by the ſum of 8 and 5, gives — — — 585

One third of 7 multiplied by 5, gives — — 11$\frac{2}{3}$

Then the ſum 596$\frac{2}{3}$ of theſe two products, multiplied by 6 and divided by 4, gives 895 for the number of ſhot contained in that pile.

CASE I.

When the pile is complete then $b=1$, and the ſum A. becomes $3a+2z-1 \times$ by $\frac{1}{6}z.z+1$. Which gives this

General RULE *for a complete pile.*

To three times the upper row add twice the corner row leſs one.

Multiply the ſum by the product of the corner row, by the corner row more one, and divide the product by 6.

If the upper row be 20, and the corner one 12; then 3 times 20, added to 23, gives — — — 83

Multiply 83 by 12, this product by 13, and divide by 6, which gives 2158 for the number of ſhot required.

CASE II.

When both a and b become unity, the ſum A becomes $\frac{1}{6}z.z+1.2z+1$, which gives this

General

General RULE *for a complete square pile.*

Multiply the corner row by that row more one, multiply this product by twice the corner row more one, and divide by 6.

If the corner row be 50, then $\frac{1}{6}$ 50 . 51 . 101, or 25 . 17 . 101, gives 42925 for the number of shot required.

N. B. By dividing before the multiplication is performed, as we have done, and which is always possible, the operation becomes shorter.

CASE III.

When $b=a+1$, the series becomes $a.a+1, a+1.a+2$, and if each of these terms be divided by 2, it will be that of a triangular pile, and because $b=a+1$, the sum A divided by 2, gives $\overline{2a+z-1}+\overline{2a+z+1}+\frac{1}{3}\overline{z+1}.\overline{z-1}\times$ by $\frac{z}{8}$.

General RULE *for triangular incomplete piles.*

To twice the side of the upper row, add the corner row less one, and the corner row more one.

To the product of these two numbers, add one third of the product, the corner row less one by the corner row more one, and multiply the sum by one eighth of the corner row.

If the side of the upper row be 26, and the corner 20; then twice 26 added to 19, gives 71; twice 26 added to 21, gives —— —— —— 73
And 71 multiplied by 73, gives —— 5183
One third of 21 multiplied by 19 —— 133
The sum 5316, multiplied by 20, and divided by 8, gives 13290, for the number of shot contained in the pile.

CASE IV.

When *a* is unity, the ſum in the laſt caſe becomes $\frac{1}{6}z.z+1.z+2$, which gives this

General RULE *for a complete triangular pile.*

Multiply the baſe by the baſe one more, this product by the baſe more two, and divide by 6.

If the baſe be 40, then 40 by 41, by 42, and the product divided by 6, gives 11480 for the number of ſhot contained in this pile.

Theſe are all the different rules that can be given upon that ſubject, and to ſave the reader the trouble of computation, we ſhall inſert here four large tables containing the number of ſhot in 2912 complete piles. The firſt column of theſe tables contains the number of the corner rows, and the upper horizontal line the number of the upper ranges. The number of ſhot in a pile is againſt the number of the corner row, and under that of its upper range. The laſt column contains the number of ſhot in a triangular pile, oppoſite to the number of its corner row in the firſt column.

PART II.

Construction of GUNS.

WHAT has been ſaid in the Introduction, with regard to the proper length of pieces, and the properties of different chambers in mortars, will enable us to form ſome general conſtructions of pieces, deducted from experiments and theory, and therefore leſs liable to exceptions, than thoſe hitherto given by others, which

which ſeem to have no other foundation, than the particular fancy of the contriver, and generally a bare imitation of others. Before we proceed any farther, it is neceſſary to give the names of the ſeveral parts of which pieces are compoſed, in order that what is ſaid may be clearly underſtood.

Names of the ſeveral parts of a gun.

Plate I. Fig. I.

A B. The length of the gun.
A E. The firſt reinforce.
E F. The ſecond reinforce.
F B. The chace.
H B. The muzzle.
A h. The caſcable.
A C. The breech.
C D. The vent field.
F I. The chace girdle.
r s. The baſe ring and ogee.
t. The vent aſtragal and fillets.
p q. The firſt reinforce ring and ogee.
v w. The ſecond reinforce ring and ogee.
x. The chace aſtragal and fillet.
z. The muzzle aſtragal and fillets.
n. The muzzle mouldings.
m. The ſwelling of the muzzle.
A i. The breech mouldings.

The vacant cylinder, wherein the powder and ball are lodged, is called the Bore, and the entrance of the bore, the Mouth of the Gun. The cylindric parts T, by which the gun is fixed upon its carriage, are called Trunnions; and the handles on braſs pieces, are called Dolphins, from the fiſh whoſe form they repreſent. The diameter of the bore is called the Caliber of the Piece. Laſtly, the difference between the diameters of the ſhot and the bore, is called the Windage of the Gun.

REMARKS

REMARKS.

The length of a gun is always reckoned from the hind part of the base ring, or beginning of the cascable, to the extremity of the muzzle. The second reinforce begins at the same circle where the first ends; and the chace at the same circle where the second reinforce ends.

The first reinforce includes the base ring, ogee next to it, the vent field, vent astragal, and first reinforce ring; the second reinforce, the ogee next to the first reinforce ring, and the second reinforce ring; and the chace, the ogee, next to the second reinforce ring, the chace girdle and astragal, the muzzle and astragal. The trunnions and dolphins are always placed on the second reinforce; the first, so as the breech part may weigh something more than the muzzle part, to prevent the piece from kicking up behind when it is fired; which it will always do so long as the center line is placed below that of the piece, as has been the custom ever since their invention. On the contrary, the dolphins are so placed, that when the gun is suspended thereby, the breech and muzzle parts may equally poise.

The artillerists here differ in the names of several parts; not one of them can tell precisely how far the muzzle reaches, nor the cascable; for some call the swelling the muzzle, others the breech mouldings, the cascable, and say, that the button is a separate part by itself, and not included in the cascable.

As no one has hitherto attempted to write upon Artillery in *English*, and to fix the names, it is no wonder that the practitioners differ, since they have no guide to go by. The only thing we could do, was to fix the names of the parts in the most convenient manner to their construction, and to prevent confusion. We have called the part from the beginning of the muzzle astragal to the mouth, the Muzzle; because that astragal deriving its name from the muzzle, it seems therefore

that

that the muzzle ſhould reach ſo far. As to the caſcable, it cannot properly be determined otherwiſe than we have done; ſince it is commonly ſaid, that a piece is of ſuch a length, excluſive of the caſcable; it agrees likewiſe with what general *Armſtrong* ſays in his Conſtruction, as well as the diſtinction made by the founders and practitioners.

Formerly pieces were diſtinguiſhed by the names of Sakers, Culverins, Cannon, and Demi-cannon; but at preſent their names are taken from the weight of their ſhot; as for example, a 12 or 24 pounder, carries a ball of 12 or 24 pounds weight.

As moſt conſtructions of authors agree in general, and differ only in ſome particulars, we ſhall give that of general *Armſtrong*'s, formerly ſurveyor-general of the ordnance, which appears to me leſs deficient than any that have hitherto been given, which are

General RULE *for braſs and iron guns.*

The length of the gun being divided into 7 equal parts; the length of the firſt reinforce A E, is two of theſe parts; the ſecond E F, one, and a diameter of the bore; ſo that the chace F B is four of theſe parts, wanting a diameter of the bore.

The diſtance from the hind part of the baſe ring, to the beginning of the bore, that is, the breech A C, is always equal to the thickneſs of the metal at the vent. The trunnions T, are always a caliber in length, and as much in diameter, clear of the ſecond reinforce ring, and placed in ſuch a manner, that a right line drawn through their centers touches the lower part of the bore, as in the fourth figure, where that line is marked a. b, and paſſing through the third diviſion; that is to be three ſevenths from the hind part of the baſe ring. The length of the caſcable A h, is always two calibers and a quarter.

Theſe

Theſe diviſions are in general made by all nations, only the trunnions are placed half a caliber more backward by the *French* *.

General dimenſions of braſs guns.

The caliber of the gun is divided into 16 equal parts.

The thickneſs of metal at the baſe ring from the bore, is — — — 16.

At the end of the firſt reinforce ring, — 14.5

At the ſame place, for the beginning of the ſecond reinforce, — — 13.5

At the end of the ſecond reinforce, — — 12.5

At the ſame place for the beginning of the chace, — — — 11.5

At the end of the chace or muzzle, the mouldings excluded, — — — 8.

MOULDINGS.

Breadth of the { baſe ring, — — — 1.5 inches.
ogee, next to the baſe ring, — — 2. }

From the ogee to the fore part of the aſtragal, a caliber.

The fillets of the aſtragal, are each — .28

The aſtragal, or half-round — — .56

Total of the aſtragal and fillets, — — 1.12

At the firſt and ſecond reinforce ring, the fillets are — — — .25

Breadth of the firſt and ſecond reinforce rings — — — 1.25

The ogees next to theſe rings, — — 1.5

The fillets at the muzzle, — — .25

* This figure does not anſwer to the following conſtructions, but it is ſufficient to ſhew the reader how to proceed, according to the given dimenſions.

The

The muzzle ogee, in a 12 pounder and upwards, is 1.25 inches; but in a 9 pounder and under, it is an inch only. The chace girdle and aſtragal is one caliber. The ſpace from the mouth of the gun to the muzzle aſtragal, in an 18 pounder and upwards, is equal to a diameter of the ſecond reinforce ring; but in a 12 pounder and under, it is equal to the diameter of the firſt reinforce ring.

The riſing of the mouldings at the firſt and ſecond reinforces, is an eighth of an inch; and the riſing of the baſe ring is determined by laying a ruler to the extremities of the firſt and ſecond reinforce mouldings. The ſwelling of the metal at the muzzle is always equal to the diameter of the ſecond reinforce ring.

CASCABLE.

From the hind part of the baſe ring, to the fore part of the fillet next to the bottom, $\frac{1}{3}$ of a caliber.

From the fore part of the fillet next to the button, to the centre of the button, one caliber.

From the hind part of the baſe ring, to the hind part of the fillet, between the two * ogees, $\frac{1}{6}$ of a caliber.

Diameter of the fillet next to the button, 1.5 caliber.

Diameter of the neck, $\frac{3}{4}$ of a caliber.

Diameter of the button, ſomething more than a caliber, it is ſix inches in a 24 pounder.

It muſt be obſerved, that the ſhell at the vent is 3 inches broad, and reaches from the baſe ring, to within a quarter of an inch of the vent aſtragal, leaving that ſpace for the eaſe of turning, and the vent is a fifth part of an inch.

* The reader muſt obſerve, that general Armſtrong made two ogees, though there is but one marked here.

General

General dimensions for iron guns.

The caliber of the gun is here divided into 14 equal parts.

The thickness of metal at the vent from the bore, is — — —	16 parts.
At the end of the first reinforce — —	14.5
At the beginning of the second reinforce,	13.5
At the end of the second reinforce, —	12.5
At the beginning of the chace, —	11.5
At the end of the chace or muzzle, —	8.

As to the mouldings, and the rest of the dimensions, they are much the same as before, only the diameter of the vent is here one fourth of an inch, without any reason given for it.

The lengths of the guns, according to this gentleman, were as follows; the 32 pounder brass, 10 feet; the 24 and 18 pounders, 9.5 feet; the 12 pounder, 9; the six, 8; the three, 7; and the 1.5 pounder, 6 feet.

The iron 32 pounder, 9.5 feet; the 24 and 18 pounders, 9; the 12, eight; the 9, seven; the 6, six and half; and the 3, four and half feet.

Some of these dimensions have been altered since for others, grounded upon no better reason than the former.

The reader may easily perceive the perplexity of these constructions, arising from the different scales that are used without the least necessity. That the greatest part of the mouldings should have the same dimensions, from a 3 pounder to one of 32, appears contrary to reason, and especially contrary to the rules of architecture; from whence they have been taken. To make as many mouldings in iron guns, which are rough and not turned, as in brass ones, is another blunder; but these are trifles in regard to the absurdities in general committed in these constructions; which cannot better be discovered, than by examining all the parts separately, each in their order.

Length

Length of guns.

If the continual changing the length of pieces be confidered, it will appear evident, that practice alone is infufficient to determine that which is the beft; and if the experiments hitherto publifhed on that account are examined with fome attention, it will be found, that for want of proceeding from proper principles, the refult of them is erroneous and inconclufive.

For the greateft part of them were made to difcover fuch a length as fhould carry the fhot fartheft, without mentioning what the charge fhould be; believing that the greater the velocity of the fhot is, the more its execution would be: but it has been found on the contrary by experience, that a velocity which is fufficient to carry the fhot juft through a wall, does more execution than one that is greater. Others, fuch as Mr. *Dumetz*, and the late general *Armftrong*, endeavoured to find the beft length of a piece, when loaded with two thirds of the fhot's weight; and to attain which, Mr. *Dumetz* made ufe of different calibers, which had all the fame length, *viz.* 10 feet, and he found that the 24 pounder carried its fhot fartheft.

Now, what can be concluded from thefe experiments? Nothing more, as I conceive, than that 10 feet is a better length for a 24 pounder, loaded with that charge, than for any fmaller caliber: but it does not determine, that this length is fuch, as to carry the fhot fartheft of any other; for we are not certain, whether one of 8 or 9 feet long would not be better than this, fince no trial has been made to fhew that it would not. Befides, we are as much at a lofs as ever, to know what are the beft lengths for fmaller or greater calibers.

+ From the experiments made by general *Armftrong* it was concluded, that 9.5 feet was the beft length for a 24 pounder, though that of 9 feet produced the greateft range.

As these pieces were all of the same weight, it is plain that some of them were too strong in proportion to their length; and if they had been reduced to a proper size, their ranges might probably have changed: but suppose this is in reality the best length for a 24 pounder, we are nevertheless in the dark with respect to the other calibers. So that the most that can be made of these experiments, is, that the length of the 24 pounder has been determined nearly, with regard to the charge made use of.

But it has been found since by experiments, that 8 pounds of powder are sufficient for a 24 pounder, when it is to make a breach; for the *French* used no more all the two last wars in all their sieges. This being the case, all former experiments are exploded, and consequently others ought to be made, in order to determine the best length for that charge.

But are we certain that this charge is the best that can be used? I think by no means; for we have found, that one fourth of the weight of the shot is sufficient for field-pieces, and even a less one. And we are not certain, that the same charge might not do in battering pieces, or on board of ships; so that new trials should be made first, to know the best charge before the lengths of the pieces can be determined.

The making small calibers longer in proportion than great ones, is attended with many inconveniences and of no advantage, so far as I can judge, since there is no necessity for their carrying as far as the heavy ones, which I suppose was the reason the artists went upon; but this supposition is erroneous; because there is but one certain length that is better than any other, greater or less, as we shall shew; and therefore they may as well be too long as too short.

Another inconveniency attends this practice, which is, that some of these pieces weigh above twice more than they ought to do, according to the most heavy construction, whereby their carriage from place to place

becomes

becomes more troublesome, and the expence at least one third more.

Lastly, when the lengths of pieces are not proportioned to the diameters of their shot, the experiments made with one caliber will not be of any use to any other, nor the dimensions used; and therefore as many experiments must be made as there are different calibers, as well as so many different constructions, in order to make them equally good and strong; and I may add, that this practice is the principal reason that so little improvement has been made in the construction of pieces, and that so much confusion is met with in them; whereas, if they are all the same number of diameters long, one general construction will be sufficient for all those made of the same metal; and when the dimensions of any one piece have been determined by experiments, it will serve for them all; the pieces will be similar, and their weights in the same proportion to that of their shot. Finally, the construction of all kind of pieces will be so short and easy, as that they may be comprehended in a few leaves, as will be seen hereafter.

Since then neither practice, nor any theory hitherto published, no more than the experiments made in *England* or *France*, have as yet furnished us with any satisfactory rule to proceed by, and yet Artillery cannot be improved without it: we shall endeavour to shew here, both from theory and some unexceptionable experiments, that there is a certain length of a gun better than any other longer or shorter, whereby it will carry its shot the farthest possible. For general *Williamson* of the Artillery made many experiments at *Minorca*, which are related in the introduction; whereby it appears that an eighteen pounder, which weighed 3900, and length 9 feet, carried farther than another eighteen pounder that weighed 5100, and was 11 feet long, when equally loaded, and with the same angle of elevation; it was found likewise, that nine pounds of powder was the best charge, and carried the shot farther than any other. From whence

whence it appears, that the greateſt length of this caliber ought not to exceed 9 feet; but whether it might not be leſs has not yet been tried.

Now as 9 feet is 21 diameter of the ſhot nearly, and it is very probable that all calibers, proportionably long and charged, will produce ſimilar effects, we may draw this concluſion, *that the length of pieces which carry their ſhot fartheſt does not exceed* 21 *diameter of its ſhot*; and *that their beſt charges are equal to half the weight of their ſhot.*

This will receive no ſmall degree of certainty from what we have proved in the appendix to this work, page 122, where we have ſhewn, that the greateſt velocities which cannon ſhot of different calibers can have, are always proportional to their diameters; and as their lengths ought to be in proportion to their charges, and they are proportional to the diameters of their ſhot, the length muſt therefore likewiſe be proportional to the diameters of their ſhot.

We have likewiſe proved in the ſame page, that the greateſt velocities of projected bodies have certain limits which they cannot exceed, let the force that acts upon them be what it will; which confirms that part of the experiments with reſpect to the beſt charge.

Now ſince the greateſt velocities of projected bodies are proportional to their diameters, the largeſt caliber will therefore carry their ſhot fartheſt. Conſequently, the queſtion of finding the length of a piece, ſo as to produce the greateſt range, depends on its caliber, its length, and on its charge, which we have here determined.

As theſe experiments are the beſt and only ones that ever were made on Artillery, as far as I have ſeen or know, and agree exactly with the theory we have given in the appendix, ſo we may affirm this theory to be the beſt and only one grounded upon true and unexceptional principles, and that all others hitherto publiſhed are

without

without foundation; and therefore all the conclusions drawn from them erroneous.

Though it may be convenient on some particular occasion to have guns which carry their shot as far as possible, yet in common practice this rule is not to be followed; for on board of ships these long and heavy guns would not answer so well as shorter and lighter, because short guns are easier loaded, require less room for the recoil, and are more expeditious in action; and since ships come so near together in action as they do at present, the long ranges are intirely useless: besides, the charge of half the weight of the shot is too much, and ought never to be used, one third at most is quite sufficient, and perhaps less, does more execution, and heat the guns less: all these advantages ought not to be neglected.

The length of battering pieces ought to be such, as to enter into the embrasures so far, as that the blast of explosion does not destroy them in a day's firing; in that case they may be repaired again at night, because it is impossible to prevent the effect of the blast intirely: for which reason all calibers, not exceeding a 24 pounder, may be 21 diameters long, but those above cannot be so long without inconveniencies; but the charges should never exceed one third of the shot's weight, because it has been found by experience that this charge is sufficient, and perhaps less would be better.

It must be observed, that guns should never be loaded with more powder than is just sufficient to produce the desired effect, which a skilful commander can or may always discover in practice; by which the guns will not be heated more than is necessary, and they may be fired longer without receiving much damage.

What has been said in respect to battering pieces may be applied to garrison ones; only the best charges may be given them on particular occasions, as at the beginning of an attack to oblige the enemy to begin his approaches as far as possible, or in a place situated near the

the ſea or a navigable river, to prevent ſhips from coming too near.

The field pieces ſhould have the beſt length and charges, in order to annoy the enemy at the greateſt diſtance, excepting the battalion guns, which ſhould be ſhort and light, that they may advance as well as retire as quick as the army. From whence follows this

General RULE,

That the length of guns ought to be determined from their particular uſes.

Thickneſs of METAL.

It is an univerſal cuſtom in *Europe* to make the guns with reinforces; that is, they are, as it were, made of three fruſtrums of cones joined together, ſo as the leaſt baſe of the former is always greater than the greateſt of the ſucceeding one, whereby the metal breaks off in two places on a ſudden, as the reader has ſeen in the conſtruction of pieces given here before. But ſince powder acts uniformly and not by ſtarts, it is hard to judge from whence this ridiculous cuſtom has ariſen, which ſeems to be as old as the invention of guns; and nothing but the ignorance of the effects of powder has been the cauſe of its being handed down to our time. Our veneration for old cuſtoms is ſo great, that whoever attempts to make any change is looked upon with contempt, let his reaſons be ever ſo plain and good; this I know too well by experience.

Yet I ſhall freely communicate whatever I think to be an improvement and uſeful to the public; let the conſequence be what it will, I ſhall do my duty. Since then powder acts gradually and not by ſtarts, there ſhould be no breakings off in the metal; and we have ſhewn in the remark after Theor. IV. that the piece ſhould be cylindric, from the baſe ring to the end of the

the charge, and from thence, by the nature of the explosion, a curve line bending inwards quite to the mouth of the piece: but as the construction of the curve is not very easy, and differs in the main but very little from a right line, by making the part between the end of the charge and the mouth conical, it will be sufficiently exact for practice.

When pieces were loaded with two thirds of their shots weight, the thickness of metal was then at the vent equal to the diameter of the shot; but since there is no occasion to load pieces with more than half that weight, the thickness of metal ought to be less; for which reason the present light 6 pounders are only the two thirds of the diameter of the shot thick, and their length 15 diameters; the same thickness is given to the 24 pounders, and their length is but 12 diameters; and as this thickness has been found sufficient by many trials, when the charge and length remain the same, there is no reason to make them stronger.

The strength given to iron guns is certainly more than required, supposing the charge no more than one third of the shot's weight; this has been found true by some, whose thickness at the vent was equal to the diameter of the shot, and half that thickness at the mouth.

Vent.

The common method of placing the vent is within about a quarter of an inch from the bottom of the chamber or bore: yet it is imagined, that if the vent was to come out at the middle of the charge, the powder would be inflamed in less time than in any other case. But notwithstanding that this appears so visible, and seems to be demonstrable, yet I have found the contrary, to the great surprize of the spectators. I had two mortars, the chamber of one cylindric, the diameter of the base one inch, and the axis two; the chamber of the other

concave; each of these chambers had two vents, one at the bottom, and the other in the middle, and contrived in such a manner, that one could be screwed up, whilst the other served to fire; and I found always the range of the shell greater, when the lower vent was used, than when the powder was fired by the middle one. The same thing was tried by colonel *Desaguliers* and me, with different cylindric chambers, some of which were three or four times the diameter of the base in length.

This being fact, it remains now to know, whether the same would do in mortars of a larger size, or in guns; for I must own, that after these trials, and some others of a still more extraordinary nature, which have been mentioned in the introduction, I can scarcely believe any thing relating to the effect of gunpowder, but what has been found true by a sufficient number of experiments.

BORE.

The windage, or difference between the diameters of the shot and the bore, is not the same in *England* as abroad. Suppose the diameter of a shot divided into 20 equal parts, then the diameter of the bore is 21 of these parts; the *French* suppose the diameter of the shot divided into 26 parts, and the diameter of the bore to be 27; what the proportion is in *Holland* and other parts of *Germany* I do not know; but it is evident, that the less windage there is, the truer the shot will go; and having less room to bounce from one side to another, the gun will not be spoiled so soon; for which reason I suppose, in the following constructions, the diameter of the shot to be divided into 24 equal parts, and make the bore 25, which is a medium between the *English* and *French* method. This we do not so much in order to differ from others, as on account of the convenient scale it affords, to construct not only guns thereby, but also their carriages, as will be seen hereafter.

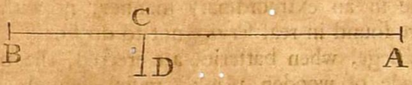
The

The *French* make little chambers in their 16 and 24 pounders, of one third of a caliber long, and as much in diameter; by this means they ſay the metal becomes thicker at the vent, and prevents its ſpoiling ſo ſoon. But as chambers are much more advantageous in other reſpects, we ſhall conſtruct ſome hereafter, ſo as to have all the advantages that can be had.

Some are for making the bottoms of the bore conical, others ſpherical; and laſtly, ſome quite flat; but I can find no reaſon to prefer one way before another, excepting the conveniency there may be in adapting the cartridges in a more eaſy manner to their form.

TRUNNIONS.

The method of placing the trunnions ſo that their axis touches the lower ſurface of the bore, as is practiſed all over *Europe*, is ſo abſurd, that it is amazing no author or artiſt has thought proper to change it; the only reaſon I ever heard given for this practice, was, that by this means they were ſtronger fixed to the gun, and of conſequence would not break off ſo ſoon as in any other place. As inſignificant as this reaſon is, it ſerves however to defend that old eſtabliſhed cuſtom.



But to ſhew the abſurdity of it; ſuppoſe A B to repreſent the center line of the bore, and C D the diſtance of the center line of the trunnions from that of the bore. Now becauſe when the piece is fired, the exploſion acts againſt the breech B, and makes the piece recoil, but being fixed to the carriage by the trunnions, endeavours to turn about the point D, whereby it preſſes alſo upon the coins under the breech B, where they by their elaſticity

city repel it upwards, and its weight brings it down again. The piece therefore acquires a pendulous motion about the center D, which causes the coins to fly off, changes its direction, and shakes the carriage with great violence, and often breaks it to pieces.

In long pieces this effect is not so sensible as in short ones; and though carriages generally break in their centers, yet the cause has never been attributed to the wrong situation of the trunnions; not even after the many accidents of that kind which have happened lately: for a short and light 24 pounder was tried at *Woolwich*, to know whether they might not be as useful in action as the light 6 pounders; but every time it was fired, it broke its carriage to pieces. From these accidents, and its recoiling more than the heavy pieces, they were rejected as useless, without thinking in the least that both inconveniencies might easily be remedied.

The piece stood upon a platform of stone quite level, which is not, nor ever has been, practised on any occasion whatever; for in the field they are placed upon the rough ground without any platform; and as the recoil is never so great in such a situation, as upon a level stone platform, this objection is to no purpose: and that this is fact beyond dispute, appears from the trials made at the same time with light 6 pounders, which recoiled likewise in an extraordinary manner, notwithstanding they are found in real service not to do so.

In a siege, when batteries are erected, the platforms are made of wooden planks, raised behind, more or less, according as it is necessary, to prevent the pieces from recoiling farther than is convenient to reload them. And since this may be done at pleasure, without the least inconvenience, the rejecting them on that account is frivolous and absurd.

To prevent these pieces from breaking their carriages is easy, if we dare break through old customs, by making the axis of the trunnions to pass through the center line of the bore, as may be seen in our construc-

tions

tions hereafter. The pretence of their breaking off from the piece is taken away, by making ſhoulders to them; beſides, this objection is only imaginary, ſince it has never been tried.

What we have ſaid upon this head is likewiſe confirmed by practice in howitzes, which, being fixed to their carriages in the ſame manner as guns, are properly nothing elſe than ſhort guns with chambers; for their trunnions are placed in the manner we propoſe, and, when fired, acquire no other motion than a backward one, without ſhaking in the leaſt the carriage, nor did their trunnions ever ſuffer.

MOULDINGS.

As they are made by way of ornament only, they depend chiefly on the maker's fancy; it muſt however be obſerved, that they ſhould be plain and ſimple, and ſuch as are uſed in architecture, from whence they have been borrowed; the metal ſhould be projected as little as can be, that the piece may lie cloſe on the carriage: the mouldings of our mortars are oddly jumbled together, without any order or judgment; and thoſe of our iron guns are more numerous than is conſiſtent with reaſon, for they have fillets on both ſides the firſt and ſecond reinforce rings, which are not uſed in braſs pieces; and as theſe mouldings are not turned in iron, they appear ridiculous, and more ſo in ſwivel guns, which have as many as thoſe of the largeſt caliber.

MUZZLE.

The ſwelling of the metal at the muzzle ſeems to have been made merely to make the pieces look graceful, or perhaps to appear of a larger caliber to an enemy at a diſtance than they really are. When they are too heavy, the piece is liable to bend at the neck when heated with much firing, which makes it either break

or

or bend, and ſo become uſeleſs. Some are of opinion, that the metal ſhould be as high at the muzzle as at the baſe ring, that the viſual ray over the metal may be parallel to the center line of the bore, which they imagine to be neceſſary for laying or pointing the piece in a proper manner; but thoſe who are for this practice are very little acquainted with real ſervice: for as the ſhot deſcends in its flight by the force of gravity, the piece muſt be laid higher than the object to be hit; ſo that when the metal is equally high before and behind, the object is hid intirely by the thickneſs of the metal, and conſequently the piece can never be laid true; whereas if the height of the metal be leſs at the muzzle than at the breech, the elevation of the piece, when pointed at the object, will anſwer the deſcent of the ſhot at a certain diſtance, and the ſkill of the gunner will be ſufficient to make a proper allowance when the object is either farther or nearer.

Cascable.

They are made of various figures; ſometimes like a bunch of grapes, or as the heads of different kinds of animals: the *French* diſtinguiſh their calibers by the different forms of the caſcables; but as this is expenſive when they are well carved, and looks paltry when not well done, the manner of making them quite plain, with a button and a few breech mouldings, as we do here, ſeems in my opinion much neater, and is leſs expenſive. It is true, that the diſtinguiſhing the different calibers is very proper; but this may be done in another manner, more agreeable to the ſight, and cheaper.

Line of Direction.

Formerly pieces were made with a cavity upon the baſe ring, and a button upon the higheſt part of the muzzle, whereby they were directed in the ſame manner

as

as fowling-pieces are; but how this line came to be left off in latter times I cannot tell; for to find the center line of a piece every time it is to be fired with a plummet or an inſtrument, as is the cuſtom, is very tedious, uncertain, and unmaſterly: for as it is impoſſible to turn the outſide of a piece true to the bore, conſidering the bluntneſs of the tools and the heavineſs of the engine, the center line can never be found to any tolerable degree of exactneſs, by an inſtrument applied on the outſide of a piece; and when the ſhot does not hit the mark, the gunner is at a loſs to know, whether it is owing to his want of ſkill, or to this line not being rightly marked; whereby it is impoſſible he ſhould be able to form a right judgment how to direct the piece.

But when the line of direction is marked on the piece in the aforeſaid manner, and the ſhot does not hit the mark, he knows how to rectify the miſtake, becauſe the line remains always the ſame, whether it be marked right or not, which I have ſeen many times. It is ſaid, that the platforms are never rightly level, and if one wheel of the carriage ſtands higher than the other, the line of direction becomes uſeleſs; but I can find no reaſon for not laying the planks level when the platform is made, ſince I always have ſeen a level uſed; and this may even be done ſufficiently exact by the eye without a level, ſince a ſmall trifle, either on one ſide or other, cannot cauſe any great error in the laying of the piece; and in a field engagement, where no batteries are made, it is of no ſignification, whether the piece points a little to the right or left, provided it is not too high or too low.

CALIBERS.

The choice of calibers depends on two conſiderations, *viz.* they ſhould never be leſs than thoſe of other nations; becauſe in an engagement by land or ſea, the larger ſhot have always the advantage; and their diameters

meters ſhould have a ſenſible difference to diſtinguiſh their ſhot with eaſe; otherwiſe it may happen in an engagement, when men are generally in ſome confuſion, that the one will be taken for the other, as has happened to my knowledge, whereby the piece becomes unſerviceable, till the ſhot ſticking in it, has been blown out again; which ſometimes cannot be done without rendering the piece unſerviceable.

As the conſtruction of pieces, as well as that of their carriages, ought to depend on the diameter of their ſhot, methinks they ſhould be expreſſed by whole numbers as much as can be, or at leaſt by ſome eaſy fractions. Thus they ſhould be expreſſed by 3; 3.5; 4; 4.5; 5; 5.5; 6 inches; which anſwer nearly to a 4, 6, 9, 13, 18, 24, and 31 pounders. And as the diameter of a 9 pound ball is 4 inches, and may ſerve in a manner as a ſtandard to make the reſt by, I am ſorry to ſee that this caliber has been rejected lately in braſs cannon.

This is what we thought neceſſary to premiſe before we enter upon the conſtruction of pieces, to ſatisfy the reader, that they are the reſult of a well aſſerted theory, and of ſuch reaſons as ought to be well conſidered beforehand; but whether they will ſatisfy artiſts prejudiced in favour of the moſt abſurd, old eſtabliſhed cuſtoms, is what time will ſhew: the ſubject is of ſo great an importance to the nation, that it deſerves to be well examined beforehand, and proper experiments made before any change is introduced; for which reaſon I ſubmit theſe my endeavours to ſerve the public to the judgment of my ſuperiors.

General CONSTRUCTION *for braſs battering pieces.*

Plate I. Fig. 1.

Let the length AB, of the piece, be 18 diameters of the ſhot; divide that diameter in 24 equal parts for a

ſcale, whereby all the reſt of the dimenſions are determined. Make the diameter of the bore equal to 25 of theſe parts; from the hind part A of the baſe ring, to the fore part D of the vent aſtragal ſet off 40 parts; make the thickneſs of metal taken from the bore at A and D, equal to 18 parts, that is, three quarters of the ſhot's diameter, and 9 parts, or half that thickneſs at the mouth; then the lines drawn through theſe points will determine the figure of the gun, which therefore is cylindric from A to D, and conical from thence to the mouth.

The center line of the trunnions croſſes the center line of the bore at right angles, and at a diſtance of three ſevenths of the total length A B of the gun, from the hind part A of the breech; their diameter is 18 parts, as well as their length, free from the projection of the ſecond reinforce ring; the ſecond reinforce E F, is always two thirds of the firſt A E; the breech A C is 16 parts, the chace girdle F I, 14; the muzzle H B, the tenth part of the total length of the gun, which is here 43 parts, and the diameter of the ſwelling, m, of the muzle is 6 parts diſtant from the mouth.

The breadth of the baſe ring and ogee next to it are each 6 parts; the firſt and ſecond reinforce rings, and the ogees next to them, 5, the aſtragals and fillets 4; the cavetto at the mouth 2.5, and the fillets one each.

The baſe ring projects the metal by two parts, the firſt and ſecond reinforce rings by one, or rather leſs; the fillets of the aſtragals by one half, and the round part is deſcribed from a center placed in the outline of the piece. There is a circular ſhoulder about the trunnions, whoſe diameter exceeds that of the trunnions by 6 parts, and projects even with the ſecond reinforce ring.

CAS-

CASCABLE. Fig. 2.

The diſtance from the hind part A, of the baſe ring, to the center C, of the button, is 27 parts, the radius of the button 9, the breadth of the quarter round 2, the ogee 5, and the fillets one each. From the center C of the button, draw lines to the extremity of the baſe ring E, F, in which find the center O, ſo as the arc deſcribed meets the arc of the button in the line C F, and touches the ſecond fillet: theſe arcs will determine the neck; the line O p, drawn through the center O, parallel to C A, will determine the ſecond fillet, and C F, the firſt.

To deſcribe the ogee, join the extremities n, q, of the fillets; through the point q, draw the line r p, parallel to O n, produced; in theſe two lines find the centers p, ſo as the arcs deſcribed through the points n q, meet in the middle of the line n q: the arc which determines the quarter round, is deſcribed from a center r, in p, q, produced ſo as to meet the extremity F, of the baſe ring within one part. The ſhell is 6 parts broad, and the diameter of the vent a fifth part of an inch.

MUZZLE. Fig. 3.

Take the line B K, equal to twenty parts, and erect the perpendicular I K, after having made L P, equal to 6 parts, the center I, is to be found ſo as the arc deſcribed, through the point K, ſhall meet the point L; and if through the point a, at 4 parts diſtant from H B, the line a r, be drawn perpendicular to L P, the center r, is to be found ſo as the arc deſcribed through the point L, may meet the extremity of the fillet a. The cavetto is no more than a concave quarter round.

It has been found by experiments, that when pieces have chambers, they require a leſs charge than they would do otherwiſe; for which reaſon I would make a chamber in all Pieces of 24 pound ball and upwards, whoſe diameter ſhould be two thirds the diameter of the bore,

bore, and length equal to that diameter, ſuch as is repreſented in the firſt figure. Although this chamber contains but one ninth part of the ſhot's weight of powder, yet the effect it produces is nearly equal to that of a fourth part; which is ſufficient in large pieces.

Whatever faults there may be found with the particulars of this and the following conſtructions, it cannot, however, be denied but this is the true method whereby artillery pieces ſhould be made; for ſince architecture has its certain rules whereby to conſtruct the ſeveral parts of a column from its diameter, there is no reaſon why the parts of a piece ſhould not be determined in the ſame manner.

To find the weight of metal.

The ſquare of 43, the diameter of the muzzle without mouldings, — —	1849
The ſquare of 61, the diameter at the vent aſtragal, — — — — —	3731
The rectangle, or main plan of theſe diameters, 43 and 61, — — —	2623
The ſum of theſe three products added, —	8193
Which multiplied by one third of 392, the length D B, — — —	1070552
The ſquare of the diameter 61, multiplied by 40, the length A D, — —	148840
Four times the cube of 18, for the trunions, caſcable, and mould, — —	23328
The ſum of theſe laſt three products added,	1242720
The ſquare of the bore 25, multiplied by its length 416, — —	260000
The difference between theſe two laſt ſums,	982720
The ſquare of the diameter is to the area of the circle, as 452 to 355, — —	771826

Theſe are cubic parts of the ſhot's diameter, divided into 24 equal parts: and as a cubic foot of gun metal weighs 459 pounds, according to our tables, or 192 cubic inches 61 pounds; the laſt ſum reduced in this proportion gives 245215.

But the cube of 24, the diameter of the ſhot, is to the cube of 4, the diameter of a 9 pound ball, as 216 to unity, ſo is 245215 to 1135 pounds, the weight of a 9 pounder; and if this number be divided by 9, we ſhall have 126 pounds of metal for every pound of the ſhot's weight. Conſequently the weight of the ſhot of any gun, according to this conſtruction, multiplied by 126, and the product divided by 112, gives the weight of the gun.

Length and weight of battering pieces.

Old Pieces.

Calib.	Length.	Weight.
6	8 : 0	19 : 0 : 0
9	9 : 0	25 : 0 : 0
12	9 : 0	29 : 0 : 0
18	9 : 6	48 : 0 : 0
24	9 : 6	51 : 0 : 0
32	10 : 0	55 : 2 : 7
42	9 : 6	61 : 2 : 10

New Pieces.

Calib.	Length.	Weight.
12	6 : 7	13 : 2 : 0
18	7 : 6	20 : 1 : 0
24	8 : 4	27 : 0 : 0
32	9 : 2	36 : 0 : 0
36	9 : 6	40 : 2 : 0
42	10 : 0	47 : 1 : 0
48	10 : 6	54 : 0 : 0

The lengths of pieces are in feet and inches; old guns of the ſame caliber are not always of the ſame length, nor of the ſame weight; theſe given here are thoſe moſt commonly uſed at preſent; but for what reaſon the 32 pounder is longer than the 42 is only known to the maker.

Remarks

Remarks on this conſtruction.

We have ſhewn in the Introduction, that the guns ſhould be cylindric as far as the charge reaches, and from thence conical to the mouth; and therefore the conſtruction is conformable to the theory: we have likewiſe ſhewn, that the center line of the trunions ought to paſs through the center line of the bore; for when it is lower, as has hitherto been the cuſtom, the carriages are deſtroyed in a ſhort time; the diſtance of the trunions from the breech is the ſame in both, and we found it likewiſe to be right by computation: the length of the 36 and 42 pounders is agreeable to that commonly given to battering pieces; and ſince both theſe calibers weigh leſs than the old 24 pounders, they may be uſed inſtead thereof, as well as the 48 pounder, which weighs very little more than ſome 24 pounders, eſpecially as a breach is much ſooner made by large calibers than by ſmall ones; and that they are ſtrong enough we are certain, ſince our preſent field-pieces, whoſe ſtrength is to that of theſe in the proportion of 8 to 9, have been found by repeated experiments, to bear any firing whatever; and they need not be loaded but with one fourth of the ſhot's weight, when they are made without chambers, ſince the force of a 32 pounder, loaded with 8 pounds of powder, is greater than that of a 24 pounder loaded with 8 pounds, in the proportion of the weights of their ſhot; that is, in proportion of 4 to 3; and the force of a higher caliber is ſtill greater.

It is true that theſe new pieces would recoil more than the old, if they were loaded with the ſame charges, which is not the caſe; beſides, it may be eaſily prevented, by allowing a greater ſlope to the platform. Conſequently the pieces, according to this conſtruction, have greatly the advantage over the old ones.

Construction of iron battering and garrison pieces.

Let the length A B be 21 diameters of the shot, divide that diameter into 24 equal parts as before, make the diameter of the bore 25; from the hind part A of the base ring, to the fore part D of the vent astragal, set off 48 parts; make the thickness of the metal, taken from the bore at A and D, equal to 25 parts, and 12 at the mouth B.

The center line of the trunions crosses the center line of the bore at right angles, at the distance of three sevenths of the total length of the gun, that is nine diameters from the hind part A of the breech: their diameter is 24 parts, as well as their length, free from the progression of the second reinforce ring; the first reinforce 9 diameters and 3 parts; the second 5 diameters and 9 parts; the breech A C, 24 parts; the muzzle H B, 50; the chace girdle F I, 16; the diameter of the swelling at the muzzle is 6 parts distant from the mouth; and the rest as before.

By the same manner of computation as before, I find two hundred weight of metal for every pound of the shot's weight. Hence we have the following,

Iron battering and garrison pieces.

Caliber.	Length.	Weight.
3	4 : 10	6 : 0 : 0
4	5 : 4	8 : 0 : 0
6	6 : 1	12 : 0 : 0
9	7 : 0	18 : 0 : 0
12	7 : 8	24 : 0 : 0
18	9 : 0	36 : 0 : 0
24	9 : 8	48 : 0 : 0
32	9 : 8	56 : 0 : 0

Observe,

Obſerve, that the 32 pounder is but 19 diameters long; the thickneſs of metal at the breech 24, and 11 at the muzzle. Experience has ſufficiently ſhewn in this laſt war, that iron guns ſtand much better, in making a breach, than the braſs; for the latter have failed in all the ſieges they were uſed.

I can affirm, that a hundred and a half of metal is ſufficient for one ponnd of the ſhot's weight, provided the guns are made of good virgin ore: and one ſhould think it would be the intereſt of the nation, to make uſe of the beſt that is to be found in the country for that purpoſe.

Beſides, a ſet of 6, 7, 12, 18, 24. 32 of braſs pieces, weigh 22700 weight, which, at 130 *l. per* ton, coſt 1475 *l.* 10 *s.* and the ſame ſet of iron weighs 19400, a ton coſts 16 *l.* and the whole ſet 155 *l.* 4 *s.* So that 9 ſets of iron coſt no more than one of braſs.

Conſtruction of braſs pieces for ſhips.

As long guns are very inconvenient on board of ſhips on account of the difficulty in loading them, we ſhall ſuppoſe the length A B to be 15 diameters of the ſhot, which diameter being divided into 24 equal parts, as before, and the diameter of the bore being likewiſe 25 parts; the diſtance AD is 40 parts; the breech AC 18; the thickneſs of the metal at A and D is 20, and 10 at the mouth B; the reſt of the conſtruction is the ſame as before; only the diameter and length of the trunions are 20 parts each.

By the ſame manner of computing the weight of metal as before, we ſhall have 124 pounds of metal for every pound of the ſhot's weight; which gives the following table.

Brass ship-guns.

Caliber.	Length.	Weight.
3	3 : 6	3 : 1 : 17
6	4 : 4	6 : 2 : 14
9	5 : 0	10 : 0 : 0
12	5 : 6	13 : 1 : 3
18	6 : 4	20 : 0 : 0
24	7 : 0	26 : 2 : 7
32	7 : 6	35 : 1 : 17
36	7 : 10	40 : 0 : 0
42	8 : 4	46 : 2 : 0
48	8 : 6	53 : 0 : 14

Remarks on this construction.

In this construction we have not considered the strength so much as the weight, on account of the recoil; for should that be too great it might be attended with great inconveniency, such as tearing the tackle. But when these guns are loaded with one fourth of the shot's weight, if there are no chambers made, the recoil will be but little greater, or perhaps no more than that of old guns loaded with half of the shot's weight: this being the case, there is not the least reason to make pieces so heavy as at present, nor so long: for if it be considered that ships may carry 12, 18, 24, 36, 42, 48 pounders of this new construction, instead of 6, 9, 12, 18, 24, and 32 pounders of the present, and at the same time carry less burthen; it must appear to every rational person, what advantage such a ship must have above an

 enemy's

enemy's of the ſame rate. To illuſtrate this by an example, we ſhall give here a liſt of the guns, length and weight, which are on board the *Royal George*.

Pr.	Num.	Length.	Weight.	Total.
42	28	9 : 6	61 : 2 : 10	1820
24	28	9 : 6	51 : 0 : 0	1428
12	28	9 : 0	29 : 0 : 0	812
6	16	8 : 0	19 : 0 : 0	304

Total 4366 or 218.3 tons.

A new ſet of guns.

Pr.	Num.	Length.	Weight.	Total.
42	28	8 : 4	46 : 2 0	1302 : 0 : 0
32	28	7 : 6	35 : 1 17	991 : 3 : 1
24	28	7 : 0	26 : 2 7	743 : 3 : 21
18	16	6 : 4	20 : 0 0	320 : 0 : 0

Total —— 3357 : 2 : 22
Total in tons — 167.8
Difference —— 50.5

It muſt be obſerved, that inſtead of 28 pieces of 42 pounders (formerly taken from the *French*) which are at preſent on board, the ſame number of ours are to be put in their place.

Hence it appears, notwithſtanding, that there are 28 pieces of 32 pounders in the new liſt, inſtead of 28 twelve pounders, and 16 eighteen pounders inſtead of the ſame number of ſixes; yet the difference between the total weights is 50.5 tons, an object too conſiderable not to be obſerved. Beſides, the new guns being ſhorter than the old, they may be fired much faſter.

That the ſtrength of theſe guns is ſufficient appears from the trial of 2 twelve pounders made for admiral *Keppel*; they were loaded with 12 pounds of powder each time,

time, and stood the proof, without receiving any damage; and I may venture to say, that they would stand any number of firings with the common charge.

General construction for iron ship guns.

Let the length of the piece be 15 diameters of the shot; the diameter of the bore 25 parts of the shot's diameter divided into 24, as before; the distance AD, 40 parts; the breech AC, 24; the thickness of metal at the vent 24, and half that thickness at the mouth; the diameter and length of the trunions 24 each, and the rest of the construction the same as before.

By the same way of computing as before, we shall find 140 pounds of iron, or a hundred and a quarter, for every pound weight of the shot: supposing that 108 cubic inches of cast iron weigh 29 pounds, according to our table of specific gravities.

Iron ship guns.

Old pieces.

Calib.	Length.	Weight.
3	4 : 6	7 : 1 : 7
4	6 : 0	12 : 2 : 13
6	7 : 0	17 : 1 : 14
9	7 : 0	23 : 2 : 2
12	9 : 0	32 : 3 : 3
18	9 : 0	41 : 1 : 8
24	9 : 0	48 : 0 : 0
32	9 : 6	53 : 3 : 23
42	10 : 0	55 : 1 : 12

New pieces.

Calib.	Length.	Weight.
3	3 : 6	3 : 3 : 0
6	4 : 4	7 : 2 : 0
9	5 : 0	11 : 1 : 0
12	5 : 6	15 : 0 : 0
18	6 : 4	22 : 2 : 0
24	7 : 0	30 : 0 : 0
32	7 : 6	40 : 0 : 0
42	8 : 4	52 : 2 : 0
48	8 : 6	60 : 0 : 0

Remarks

Remarks on this conſtruction.

The making iron pieces in ſuch a manner as not to be heavier than is neceſſary, nor yet too weak, ſo as to be in any danger to break when fired briſkly for ſome time, is of the greateſt importance, inſomuch as all our ſhips, one or two excepted, are provided therewith; for by making them too heavy the ſhips cannot carry ſo many large large calibers as they otherwiſe might, which is agreed by the beſt judges to be a great diſadvantage; if, on the other hand, they ſhould be ſo weak as not to bear a briſk firing, the burſting of a piece in an action might create ſuch a confuſion as to cauſe the loſs of the ſhip. But to prove beyond doubt that no danger can be apprehended from guns made according to this conſtruction, provided the iron is good (ſuch as that of the *Carron* company) appears from the trial of 2 three pounders made for lord *Egmont*; for they both ſtood the ordnance proof loaded with three pounds of powder, and I am certain they would have ſtood if they had been loaded with double that charge. There was alſo made 2 ſix and 2 twelve pounders for Monſ. *De Malo*, the *Portugueſe* envoy; and they ſtood their proof, and would have done it, if they had been loaded with much greater charges than the weight of their ſhot. Now ſince all the calibers are proportionally ſtrong according to their charges, the one being found ſtrong enough by practice, all the reſt muſt be ſo too. Secondly, we have a great many 6 and 9 pounders that were caſt formerly, and which have been uſed a great while, and are leſs thick at the muzzle aſtragal than the new ones: this being an undeniable fact, proves again, that the new are of a proper ſtrength. The reaſon that the preſent guns are ſo much heavier than the new, is owing to their greater length; beſides the charges of powder have hitherto been greater than was neceſſary, and the ſtrength of the pieces has, or ought to have been

been made in proportion. With regard to the length of theſe new pieces, they are ſuch as are conceived by ſome of the beſt ſea officers to be much more convenient than if they were longer, on account of the rope rammer they are obliged to uſe; for in long pieces, if the rope is hard and ſtiff, it is bent with great difficulty, and if not, will ſcarcely ſuffice to ram the ſhot home.

Guns of a new conſtruction uſed in the ſeveral men of war.

Num. of guns.	Weight of old.	Weight of new.	Num. of ſhips.	Weight of old number.	Weight of the new number.
100	4367. 3	2556. 0	5	21838. 3	12780
90	3537. 3	2001. 0	9	31839. 3	18009
80	3108. 3	1827. 0	7	21761. 1	12789
74	3091. 0	1840. 2	32	98912. 0	58896
70	2997. 0	1796. 2	10	29970. 0	17965
64	2543. 3	1305. 0	23	58506. 1	30015
60	2177. 3	1185. 0	30	65332. 2	35550
50	1881. 1	1035. 0	19	35743. 3	19665
44	1365. 2	705. 0	8	10924. 0	5640
40	1234. 2	312. 2	9	11110. 2	2812
36	963. 3	450. 0	7	6746. 1	3150
32	956. 2	435. 0	28	26782. 0	12180
28	593. 2	285. 0	23	13650. 1	6555
24	531. 3	255. 0	12	6381. 0	3060
20	421. 2	191. 1	15	6322. 2	2869

Total of the Weights —— —— 445820 : 241935
Difference —— —— —— 20388500 or 10194¼ tons.
Difference of the expences —— 163108 l.

If to this we add the difference 26321 l. between the braſs guns of the *Royal George* and the ſame ſet of iron, we get 189429 *l.* for the difference between the expences of the old and new ſet. And if the number of guns on board of the ſloops and thoſe in the garriſons, as well as thoſe which ſerve in the field, it may perhaps amount to as much more.

Hence

Hence every ſhip may carry very nearly double calibers of theſe new guns to thoſe of the old ones, and that with ſafety, and be leſs burthened at the ſame time, as has been fully proved: the great advantage of ſuch a change muſt be plain to all ſuch as are concerned in naval affairs. I muſt obſerve one thing more, that the ſmall charge we propoſe may appear inſufficient in calibers under a 24 pounder; but when it is conſidered, that when ſhips come to a proper diſtance, the ſmall ſhots have as much chance to penetrate the ſhip as the large, though their effect is leſs in proportion; but at a great diſtance the reſiſtance of the air is greater in proportion as the diameter diminiſhes, as Mr. *Robins* has rightly obſerved.

But as all commanders make, or ought to make a point of it, to come cloſe to an enemy before they begin to fire, there is no reaſon to fear but that theſe ſmall calibers are as uſeful as any others.

Number

Number and caliber of guns on board the ſeveral men of war.

Old Eſtabliſhment. •

N°	42	32	24	18	12	9	6	4
100	28		28		28		16	
90		26		26	26		12	
80		26		26		24	4	
74		28		28		18		
70		28		28		14		
64			26		26	12		
60			24		26		10	
50			22		22		6	
44				20		20	4	
40				20		20		
36					26		10	
32					26		6	
28						24		4
24						22		2
20					10		10	

New Eſtabliſhment propoſed.

N°	48	42	32	24	18	12	9	6
100	28		28	28		16		
90		26	26	26		12		
80		26	26		24	4		
74		28	28		18			
70		28	28		4			
64			26	26	12			
60			24	26		10		
50			22	22		6		
44			20		20	4		
40			20		20	4		
36				26		10		
32				26		10		
28				24		4		
24				22			2	
20				10		10		

• The firſt column contains the number of guns which the ſhips carry, according to the preſent eſtabliſhment; the numbers in the firſt horizontal line expreſs the calibers uſed on board of the men of war; and the number of each ſort are under them oppoſite the number the ſhips carry.

Conſtruction

Construction for light field pieces.

Let the length A B of the piece be 14 diameters, the diameter of the shot divided into 24, and the bore 25 as before; the thickness A C of the breech 14, the distance A D 39; the thickness of metal at the vent A D 16, and 8 at the mouth; the diameter and length of the trunions each 16 parts, and the rest of the construction as in the first.

A ring of metal is cast under the cascable in these light pieces, as is seen in figure the second, which serves to fasten the head of a screw, that is used instead of coins to raise the piece by: this ring is described from the same center, and with the same radius as the neck; the diameter of the hole to receive the bolt is 5 parts, and the thickness of the ring is 4 parts.

By the same way of computing the weight of metal as after the first construction, we find about 85 pounds of metal for every pound of the shot's weight, which gives the following dimensions.

FIELD PIECES.

Present.

Calib.	Length.	Weight.
3	3 : 6	2 : 3 : 10
6	4 : 6	4 : 3 : 10
12	5 : 0	8 : 3 : 8
24	5 : 6	16 : 3 : 13

New.

Calib.	Length.	Weight.
3	3 : 3	2 : 1 : 2
6	4 : 1	4 : 2 : 5
9	4 : 8	6 : 3 : 8
12	5 : 1	9 : 0 : 10
18	5 : 10	13 : 2 : 16
24	6 : 5	18 : 1 : 5

From

From whence it appears, that the weights of the new conſtructed pieces nearly agree with thoſe uſed at preſent: the lengths of the 3 and 6 pounders new are leſs, and thoſe of 12 and 24 ſomething more than the lengths of the preſent. We have hitherto uſed but the four calibers marked above, and even the 12 and 24 very little, becauſe it has been found that theſe pieces, placed on a level platform, and loaded with one-fourth of the ſhot's weight of powder, recoil too much: yet as platforms are never made upon any occaſion without a ſlope, and in an engagement are placed upon turf, and the advantage of the ground is or may be taken, the firing theſe pieces upon a level platform made of ſtone is not an experiment to be depended upon.

Theſe light 18 and 24 pounders may ſerve in private expeditions for battering pieces, eſpecially where the road is very bad, and no heavy pieces can paſs, and yet battering pieces are required; which is the caſe where a fort or any other poſt is to be taken; for no leſs calibers are eſteemed ſufficient to make a breach, or induce the commander to ſurrender. There have been much lighter pieces made not many years ago, as a 6 pounder weighing but three hundred and a half, and which carried its ſhot very well with a pound and a quarter of powder; but it is imagined that they are attended with inconveniencies in real uſe, for which reaſon they have been rejected.

Conſtruction of iron garriſon pieces.

Let the length of theſe pieces be 18 diameters of the ſhot, and the reſt of the conſtruction be the ſame as that of iron ſhip guns: then by a like computation as before, we find $172\frac{2}{3}$ pounds of iron for every pound of the ſhot, and from thence we get the following dimenſions.

IRON

IRON GARRISON PIECES.

Calib.	Length.	Weight.
3	4 : 2	4 : 2 : 12
6	5 : 3	9 : 1 : 0
9	6 : 0	13 : 3 : 12
12	6 : 7	18 : 2 : 0
18	7 : 6	27 : 3 : 0
24	8 : 4	37 : 0 : 0
32	9 : 2	49 : 2 : 18
42	10 : 0	64 : 0 : 0

As the 32 pounder weighs about the ſame, and is nearly the ſame length as the old 24 pounder, it may well ſerve upon the ſame occaſion. As to the lengths and weights of the other calibers, I imagine them ſuch as are proper for the uſes they are commonly applied to. The 42 pounder may alſo ſerve near the ſea, or in harbours, to prevent enemy's ſhips from paſſing by, with more advantage than 24 and 32 pounders, which are chiefly uſed at preſent upon thoſe occaſions.

But if ſome of the ſmaller calibers ſhould be thought too ſhort, according to the preſent practice, they may be lengthened ſo much as neceſſary, without changing any of the other dimenſions, which do not depend on the length.

Having given general conſtructions for the ſeveral ſorts of braſs and iron cannon, which are neceſſary upon different occaſions by land or ſea, in the moſt plain and

eafy manner we could think of (which none have yet done) and as thefe conftructions are grounded on the moft plaufible reafons, fupported by theory and practice, it is hoped our endeavours will be of ufe to the public, as expences are confiderably leffened. For if the great quantity of metal required in all the guns neceffary to the nation, and the vaft number of horfes now ufed in the field be confidered, and that according to our conftruction above one-third will be faved, as likewife a proportional number of horfes, one would imagine thefe advantages fufficient to induce the directors of thefe affairs to examine well our fcheme, and to make proper trials, in order to be convinced whether what is here propofed is of any real advantage or not; at the fame time guarding againft the crafty infinuations of ignorant artifts, who find fault with improvements merely out of a felfifh vanity, without judgment or knowledge.

As we propofe to make chambers in all guns above an 18 pounder, it may be objected, that the difficulty of loading them will prevent their ufe; but as a rammer may be contrived fo, as to load thefe pieces as eafy as others, the only difference being to put the powder in cartridges, which is more than recompenfed by faving almoft half of it; befides, the pieces will not be heated fo foon, and confequently they may be fired much oftener without any danger of being damaged. When all thefe advantages are well confidered, it will be found that chambers in large cannon is an improvement not to be neglected.

We muft obferve one thing more before we leave this fubject, which is, that as we make the diameter of the bore but one 24th part larger than that of the fhot (whereas the common practice is to make it one 20th part more) if the bores of the new conftructed guns are made as ufual, they will be fomething lighter than what we have marked them in the preceding tables. But as a fhot goes much truer when it juft fits the bore, and does lefs damage to the gun, by not bouncing from one

fide

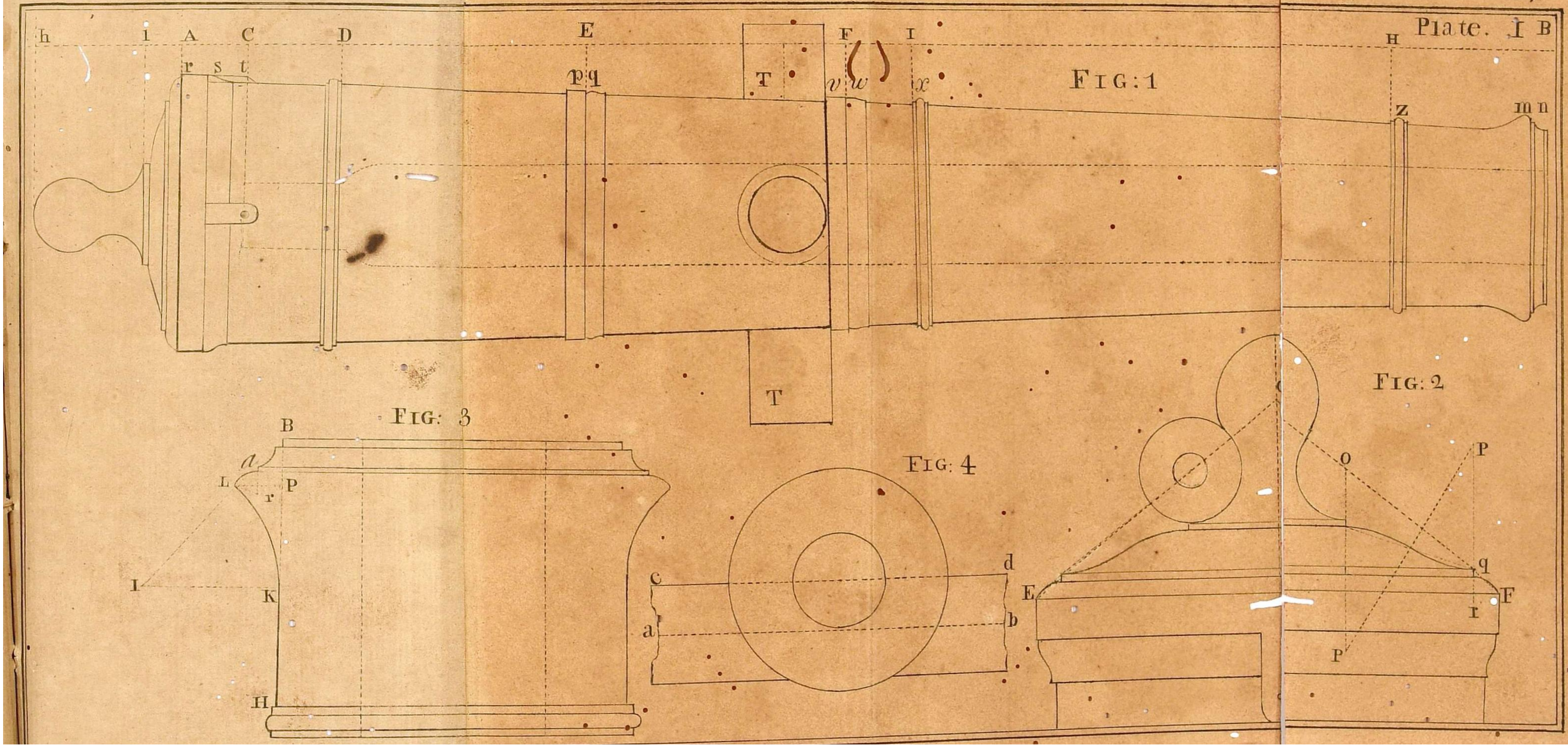


Plate. I
FIG:1
h i A C D E F I H B
r s t
p q
T
v w x
z
m n
T
FIG:2
O
P
q
E F
r
P
FIG:3
B
a
L P
r
I K
H
FIG:4
c d
a b

ſide to the other, it is to be hoped that they will be made in the manner we propoſe.

It is true that ſome artillery officers ſay, that the windage of a gun ſhould be equal to the thickneſs of the ladle; becauſe when it has been loaded for a while, the ſhot will not come out without being looſened thereby, in order to unload it; and when this cannot be done, it muſt be fired away, and ſo loſt; but as the windage of a 9 pounder, according to our conſtruction, is $\frac{1}{5}$ of an inch, this is conceived a ſufficient thickneſs for a ladle, and thoſe of a higher caliber become ſtill thicker in proportion. But ſuppoſe this thickneſs is not ſufficient, the loſs of a ſhot is a mere trifle in reſpect to the advantage got thereby; beſides, as there is always a wad before the ſhot, I do not ſee that any duſt or dirt can get into the piece; and therefore when the muzzle is lowered, the ſhot will roll out of courſe.

There is another advantage in theſe general conſtructions, which is, that the diameters of the ſhots being marked on braſs rulers at full length, and divided into 24 equal parts, they will ſerve as ſcales to draw the draughts in full lengths for the uſe of the founders and the carriage-makers, whereby the patterns may be made with great eaſe and exactneſs.

PART III.

Conſtructions of MORTARS *and* HOWITZES.

MORTARS are a kind of ſhort cannon of a large bore, with chambers. Their uſe is to throw hollow balls filled with powder, called *ſhells*; which falling upon any building, or into the works of a fortification, burſt, and their fragments deſtroy every thing within reach. *Carcaſſes* are alſo thrown out of them, which are a ſort of ſhells with five holes, filled with

 pitch

pitch and other combuftible matters, in order to fet buildings on fire; and fometimes baſkets full of ſtones, the ſize of a man's fiſt, are thrown from them upon an enemy, placed in the covert way in the time of a ſiege.

Mortars are diſtinguiſhed here chiefly by the diameter of the bore. For example, a ten inch mortar is that the diameter of whoſe bore is ten inches; there are however ſome ſmall ſorts, as coehorns and royals; the name of the firſt is derived from that of the inventor.

Sea mortars, or thoſe placed on board of ſhips, are longer and much heavier than the land. There is beſides another ſort, called howitzes, of a *German* invention, which differ from the former, in having their trunions placed nearly in the middle, and being mounted upon carriages like travelling gun-carriages.

PLATE II. Fig. 5.

The principal parts of a mortar are on the outſide the chaſe A, the reinforce B, the breech C, and the trunions D. In the inſide, the part where the ſhell is lodged, is the bore; and the part where the powder is lodged, called the chamber. The parts *n n*.

The figure of the chamber is made variouſly by different nations; the *Spaniards* uſe chiefly the ſpheric; the *French* the conic, cylindric, and the bottled or concave; the *Engliſh* make them in the form of a fruſtum of a cone. Each nation has its reaſons, good or bad, to prefer their make before that of others; but whoever conſiders theſe different forms in an impartial manner, and the reaſons given by authors for adhering to one preferable to others, will find, that nothing is leſs determined upon true principles or experiments, than the proportions of the ſeveral parts of a mortar; we ſhall therefore begin to give ſome tables of their dimenſions, and afterwards examine the different parts ſeparately, as we have done in guns, in order that the reader may diſtinguiſh their perfections and imperfections.

Dimenſions

Dimensions of the brass land mortars now in use. Fig. 5.

Diameter of the bore —	—	13	10	8	5.8	4.6
Total length of the mortar —	—	44	33	25.5	16.5	13.5
From the mouth to the reinforce	—	15.25	10	8.5	4.75	4.2
Length of the reinforce —	—	8.75	8.1	5	5	3.9
Length of the trunions from end to end		32.5	26	20	12	9.2
Diameter of the trunions —	—	7.15	6.3	5	2.75	2.15
Length of the bore —	—	24	18	13	8.5	7
Length of the chamber —	—	12	7.8	7.75	4.5	3.7
Greatest diameter of the chamber	—	6.6	4.5	4	3	2.7
Least diameter of the chamber	—	6	3.6	3.4	2.4	1.4
Diameter of the muzzle ring —	—	21	15.15	11.2	8	6.4
Breadth of the muzzle ring —	—	1.1	.8	.6	.7	.5
Breadth of the astragals and fillets	—	1.25	1.0	.75	0	0
Distant from the muzzle ring —	—	1.5	1.0	1.0	0	0
Diameter near the muzzle astragal	—	18.1	13.2	10	6.9	5.6
Diameter near the reinforce —	—	18.1	13.2	10.0	6.9	5.6
Diameter of the reinforce —	—	21	15.15	15.1	8	6.4
Breadth of the ogees —	—	1.5	1.0	1.0	0	0
Diameter behind the breech astragal	—	18.1	13.2	9.8	6.9	5.9
Chamber contains powder —	lb.	9 : 1 : 8	4 : 0 : 0	2 : 0 : 10	1 : 0 : 10	0 : 8 : 0
Weight of the mortar — —	C.	25 : 0 : 0	10 : 2 : 18	4 : 0 : 20	1 : 1 : 0	0 : 3 : 0
Weight of the shell when filled —	C.	1 : 2 : 25	0 : 3 : 2	0 : 1 : 17	0 : 0 : 13	0 : 0 : 7
Shell contains powder — —	lb.	9 : 4 : 8	4 : 14 : 12	2 : 3 : 8	1 : 1 : 8	0 : 8 : 9

N. B.

N. B. The extremity of the bore is made round, and formed by an arc, whose radius is equal to that of the bore, and terminated by the lines which form the chamber: the bottom of the chamber is semi-circular, the outside of the metal is determined by a circular arc, described from the same center as the bottom of the chamber, and touching the lines drawn parallel to its sides.

As all the necessary dimensions are set down here accurately, the reader may easily construct these mortars by the help of the plate, which shews their form; for which reason we shall insist no farther upon them.

Dimensions of sea mortars in inches. Fig. 6, 7.

Diameter of the bore	13	10
Length of the mortar	63	56
From the muzzle to the reinforce	21	20
Length of the reinforce	18	12
Length of the bore	24	30
Length of the chamber	21	15
Its greatest diameter	8.5	6.6
Its least diameter	7	6
Breadth of the muzzle ring	3	2.4
Of the muzzle, ogee, and fillet	1.9	0
From the muzzle to the astragal	0	.4
Of the astragals	0	1.6
Of the reinforce rings	1.9	0
Of the ogees next to them	4.5	2.2
Of the chace ring	1.5	0
Of the chace ogee	2.2	0
Of the chamber astragal	0	1.6
Thickness of metal at the muzzle	4.7	2.8
At the muzzle ring	5.¾	6
Near the reinforce	4.7	3.3
At the reinforce	8	6
Behind the reinforce	9.5	6
Trunions length from end to end	45.4	36

Its

Its greatest diameter — —	12	[illegible]
Its least diameter — —	10	8
Length of the part diminished —	6	0
Chamber contains powder ℔	32	12 : 8
Weight of the mortar — C.	81 : 1 : 1[illegible]	32 : 3 : 7

N. B. The thickness of metal at the muzzle, and near the reinforce, is taken from the lines produced, which determine the bore of the mortar; and behind the reinforce it is taken from the lines, which terminate the chamber. The round part or the breech of the mortar is circular, and described from the same center as the bottom of the chamber in the 10 inch, and so as to come within 3.5 inches of the end of the mortar in the 13 inch; and in both so as to touch the outlines, which are drawn parallel to the sides of the chamber.

The reader may easily perceive, that wherever stands an o in the two last tables, there is no such dimension in that mortar; for there are mouldings in one which are not in the other.

Dimensions of Howitzes *by inches.* Fig. 8.

Diameter of the bore — —	10	8
From the muzzle to the reinforce	19.4	16
Length of the reinforce ——	11.9	10.7
Total length of the howitz —	50.4	37.4
Length of the bore — —	29.2	25.9
Length of the chamber —	16.8	9.9
Its greatest diameter — —	6.5	4.6
Its least diameter — —	5.6	4
Breadth of the muzzle ring —	1.7	1.25
From the muzzle ring to the astragal	4.3	4.6
Breadth of the astragal ——	1.3	.7
Of the ogee before the reinforce	2.	1.4
Of the ogee behind the reinforce	1.7	0

Of the aſtragal — —	1.4	.7
Of the baſe ring — —	1.8	1.25
From the baſe ring to the aſtragal	2.2	0
Breadth of the aſtragal —	1.3	0
Thickneſs of metal at the muzzle	2.75	2.25
At the muzzle ring — —	5	3.4
Near the reinforce — —	3.4	2.6
At the reinforce — —	5.0	3.4
Behind the reinforce — —	4.4	2.5
Diameter of the baſe ring —	20	14.7
Diameter at the vent aſtragal —	17.5	12.5
Diameter of the caſcable —	8.25	7.6
Diameter of the button —	7	3
Diameter of the neck —	5	3.5
Breadth of the ogee and fillets	1	.9
Of the ſecond ogee and fillets	1.6	.9
Diameter of the firſt fillet —	11.13	9.5
Diameter of the ſecond —	7.64	4.5
Length and diameter of the trunion	6.	4.4
From the fore reinforce to the trunion	2.	1.2
Chamber contains powder ℔	18	4
Weight of the howitz — C.	31 : 2 : 26	12 : 1 : 11

Remarks on the conſtruction of MORTARS.

Of all the parts of Artillery, the conſtruction of mortars is the moſt variable and uncertain; almoſt every artilleriſt has ſome favourite notion or other concerning their figure. Mr. *Belidor* mentions, in his *Bombardier François*, four different chambers; namely, the cylindric, the ſpheric, the conic, and the bottled; of theſe he ſays the cylindric is the worſt, and the conic the beſt; for, ſays he, the vent being at the end of the cylindric chamber, prevents the powder from taking fire ſo quick as in the conical one; he alledges likewiſe another reaſon againſt the uſe of theſe chambers, which is, that they are ſeldom caſt ſo as their axis corresponds with

with that of the bore, whereby the direction of the ſhell becomes variable and uncertain.

But ſince there is no neceſſity for placing the vent at the end of the chamber, as he ſuppoſes, all his arguments on that account can only be againſt the preſent practice, and by no means proves their badneſs; and had he conſidered the exploſion of powder as an elaſtic fluid, as he ought, he would have eaſily perceived that the direction of the chamber, with regard to that of the ſhells, is of no conſequence, ſince the action of fired powder is every-where perpendicular to the ſurface it acts upon. Beſides, according to the experiments I made, which are mentioned in the preface, the force of powder, when fired at the end, is greater than when fired in the middle. I dare not however infer, that the ſame thing will happen in larger mortars, becauſe I have found by experience, that we ought to depend upon nothing but what has been found to anſwer in pieces of the ſame caliber; and therefore all the different ſizes of mortars ſhould be tried and examined, to determine where the vent is to be placed in the moſt advantageous manner.

We have proved in the fifth Theorem, and the examples that follow, that the action of fired powder diminiſhes in proportion as the ſurface preſſed enlarges; the ſame thing we have likewiſe found by experiments, and therefore the conic chambers are the very worſt of all.

The late General *Borgard* made his chambers likewiſe conical, terminating in a circular form at the bottom, as has been ſhewn in the foregoing tables of the dimenſions; and ſo as the ſides of the chamber produced meet the extremities of the diameter at the mouth; imagining, I ſuppoſe, that the powder acts in right lines parallel to the ſides of the chamber. Though he was one of the braveſt officers of his time, and ſerved about ſeventy years, yet his qualifications as an inventor were but very moderate.

As to the advantage of concave chambers of any kind, it conſiſts in this, that their entrance may be made narrower than thoſe of any other form, and that this is a real advantage, we have proved both by theory and practice: yet when the entrance is ſo ſmall as not to admit of a man's hand, they are not eaſily cleaned; and if any ſparks of fire ſhould remain, cannot be ſo well extinguiſhed; for which reaſon I would make them of this form only in ſea mortars, becauſe they are loaded with large quantities of powder, and in the land ones cylindric; ſince theſe latter need be charged with but little powder.

As to the vulgar notion, that mortars with concave chambers, when fired, ſhake their beds with great violence, and make the direction of the ſhell very uncertain, it is grounded upon ignorance, and deſerves no notice.

The length of mortars is no more aſcertained than the reſt of the dimenſions: the *French* make the length of the bore a diameter and an half of the ſhell; on the contrary, we make that of our land mortars two of theſe diameters, and three in the ten inch ſea mortar, which cauſes a great difference in the weights; for our thirteen inch land mortars weigh C. 25 : 0 : 0, whereas the *French* weigh only C. 13 : 0 : 0.

It is a query, whether this difference produces any material advantage in the ranges; if not, it would be unneceſſary to make them ſo long as we do, ſince this increaſe makes them ſo much the heavier. For the ſame thing (*viz.* that thoſe guns which carry fartheſt are not the beſt) is alſo true in mortars; ſince if they carry their ſhells about 12 or 1500 yards with a moderate charge, it is in my opinion ſufficient in reſpect to land mortars; becauſe when they carry farther, the hitting an object becomes ſo extremely uncertain, as to render that advantage uſeleſs; therefore all means ſhould be tried to make them as light as conveniently can be.

The

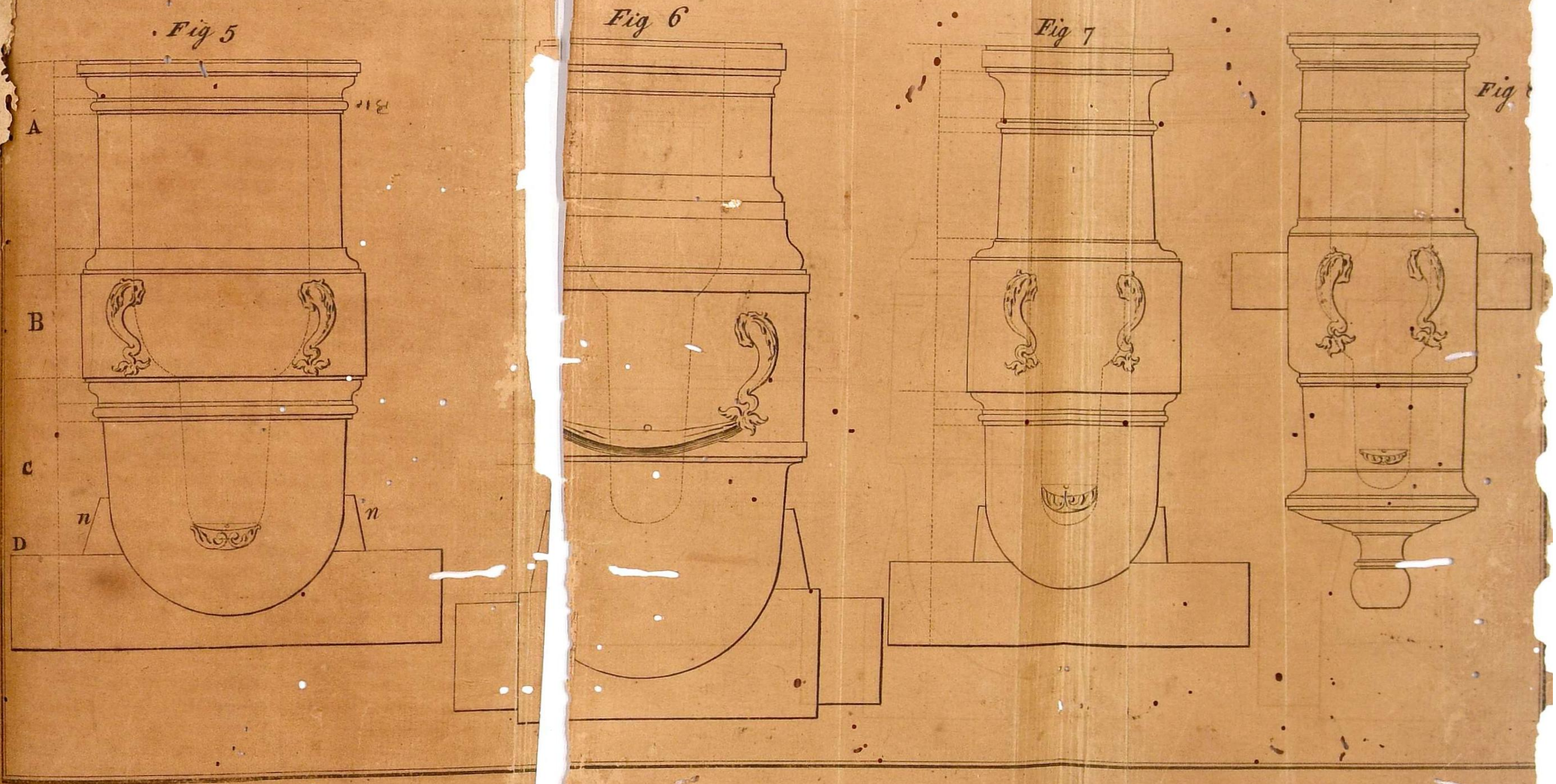
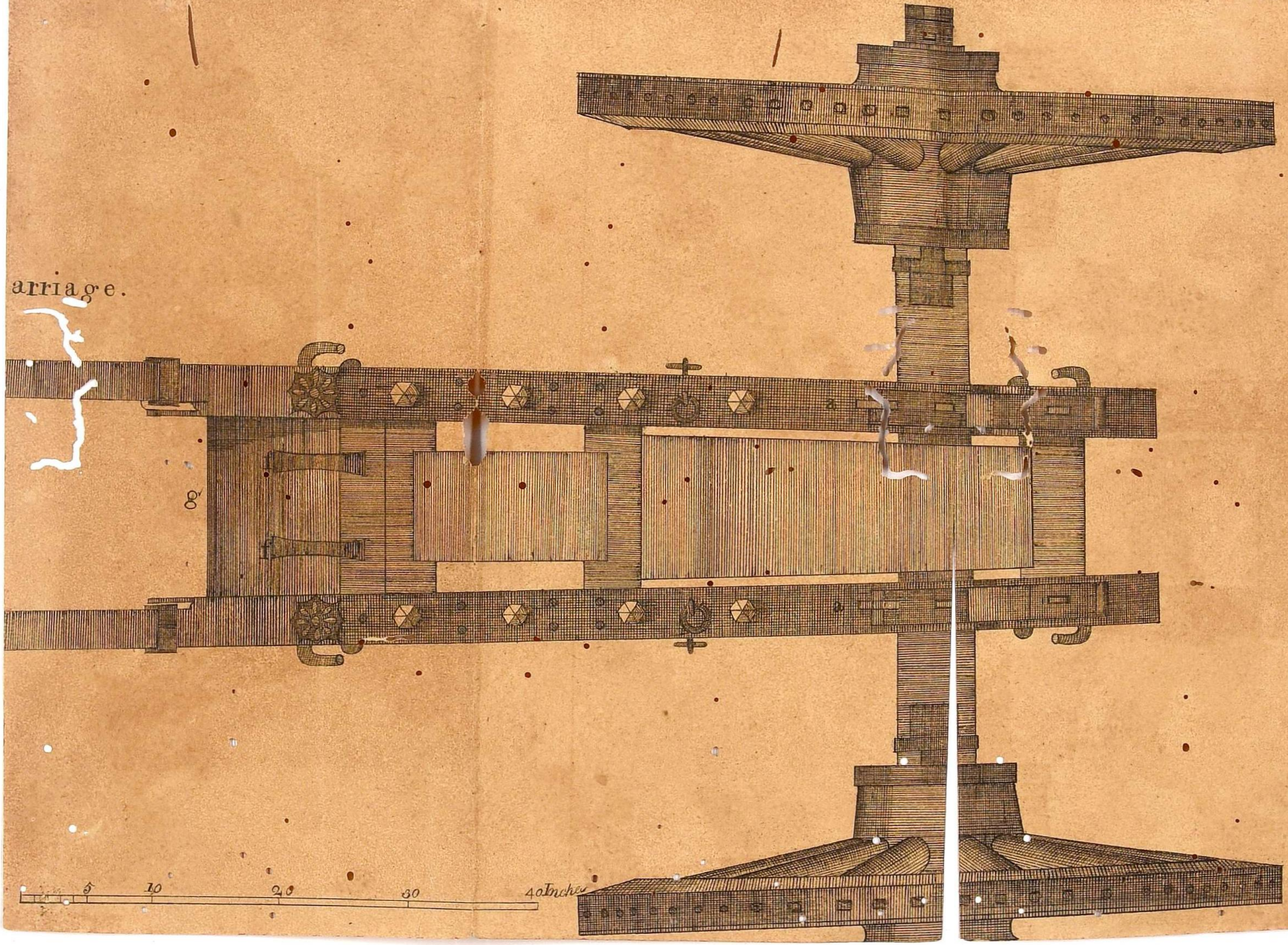


Fig 5
A
B
C
D
n
n
Fig 6
Fig 7
Fig

Pl.100

arriage.



The thickneſs of metal in the different parts of a mortar, is as undetermined as the reſt; for not any two ſorts are equally ſtrong; ſome are as much too weak as others the reverſe, and thoſe who have the direction of theſe things are ſo ſlightly acquainted with the common principles of geometry, that when a mortar of any ſize is made with proper dimenſions, and has been found in practice to anſwer perfectly well, they cannot make another either leſs or larger, that ſhall ſtill retain the properties of the former.

The reaſon is, that commonly none but workmen are employed on them, whoſe knowledge conſiſts only in imitation and gueſs. For though a workman may be very capable to execute the work, or to ſee it done, yet it can hardly be ſuppoſed that he is able to determine the proper dimenſions of the ſeveral parts.

The parts of mortars are formed in imitation of thoſe of guns; for which reaſon they make them with a reinforce. This only overloads the mortar with a heap of uſeleſs metal, and that in a place where the leaſt ſtrength is required; yet, as if this unneceſſary metal was not ſufficient, they add a great projection at the mouth, which ſerves to no other purpoſe than to make the mortar top-heavy. The mouldings are likewiſe jumbled together, without any taſte or method, though they are taken from architecture.

As there has not the leaſt hint hitherto been given, with regard to a general rule to conſtruct all ſizes of mortars by, without which, the artilleriſt cannot poſſibly underſtand what he is about, nor can he judge whether he is right or wrong, whenever he attempts to conſtruct others of a different ſize from thoſe in uſe at preſent, he muſt remain in ignorance, let him take ever ſo much pains, we ſhall give the following rules.

General

General dimensions for land mortars.

Plate III. Fig. 9.

Diameter of the bore	30	30	30
Diameter of the chamber	10	10	10
Length of the bore	54	45	40
Length of the chamber	22	21	10
From the end of the chamber to the end of the mortar	16	15	14
Total length of the mortar	92	81	74
From the mouth *a* to the reinforce *b*	30	26	22
Length of the reinforce *b c*	18	14	14
Breadth of the muzzle ring and fillets	3. 5	3	3
Breadth of the ogee next to it	3	2	2
From the ogee to the muzzle astragal	5	4	3
Breadth of the astragal and fillets	2. 5	2	2
Breadth of the ogee before the reinforce	3	2	2
Breadth of the two ogees and fillets behind the reinforce	6	5	4
Thickness of metal at the muzzle	5	4. 5	4
Thickness of metal near the reinforce	6	5	4. 5
Thickness of metal at the reinforce	7	5. 5	5
Thickness of metal at the chamber	12	12	12
Thickness of metal at the muzzle ring	6. 5	5. 5	5
Diameter of the trunions	14	13	12
Length of the trunions from the mortar	15	14	13
Chamber contains powder	*d* / 421	*d* / 442	*d* / 466
Weight of the mortar	5*d* / 6	2*d* / 3	3*d* / 5

N. B.

N. B. The chamber is cylindric, and the bottom a ſemi-ſphere; the round part of the mortar is deſcribed from the ſame center as the bottom of the chamber. The letter *d* in the content of the chamber and that of the weight of metal, expreſſes the cube of the diameter of the bore in inches; that is, $d = 2197$ in a thirteen inch mortar, and $d = 1000$ in a ten inch.

The reader may ſee that the diameter of the bore is to be divided into 30 equal parts, for a ſcale to ſet off all the reſt of the dimenſions. The ſame ſcale ſerves to conſtruct their beds, which renders the whole eaſy and uniform, a neceſſary conſequence of well ſettled principles.

Remarks on theſe dimenſions.

We have endeavoured to diſpoſe the metal in ſuch a manner, as to make the ſtrength of the parts nearly in proportion to the forces which act upon them: at the chamber it is ſufficient, though leſs than in moſt mortars now in uſe; for the thickneſs of metal there is greater than its diameter, which is more than ever has been allowed in any braſs gun whatever; it is true that the effort alſo is greater, but then an allowance has been made accordingly: we made a reinforce, merely to comply in ſome manner with the common practice, though the mortar ſhould be conical from the chamber to the mouth, according to the action of powder, as proved before; however, the difference between the reinforce and chace is no more than juſt ſufficient to admit of an ogee, whereby the mortar looks more graceful to the eye; at the mouth the projection is no greater than is neceſſary for the mouldings, more would be ſuperfluous, and make the mortar top-heavy; beſides, as we ſuppoſe it capable of being either raiſed or depreſſed, and not fixed to its bed, as hitherto the cuſtom, that operation would thereby become more difficult. As to

to the vent, we do not pretend to determine its true place, though we have always found the nearer it was to the bottom the farther the fhell went; but as thefe experiments were made with a three inch mortar only, no juft conclufion can be drawn from thence with regard to larger.

The cylindric figure of the chamber, is, in my opinion, the beft for thefe kind of mortars; for though we have fhewn that the concave figure, or thofe whofe entrance was the leaft, will throw the fhell fartheft of any with the fame charge; yet in this cafe, where but little powder is required, their entrance would become too narrow and inconvenient to clean; whereas when they are cylindric, the difference between the advantage of the one and the other will be but little, and not attended with any inconveniencies.

Colonel *Defaguliers* and myfelf made feveral experiments with different chambers, which contained the fame quantity of powder, and we found that the cylindric threw the fhell always farther than any other whofe entrance was larger, and more efpecially when they were not quite filled. We made likewife fome other experiments, which were, by putting as much powder as would fill half the chamber into a cartridge made of common writing paper, and when it was put into the chamber, fo as to be clofe to the fhell, leaving a vacancy at the bottom, it threw the fhell near twice as far as when the cartridge touched the bottom, and the vacancy was left between the fhell and the powder; we repeated this experiment feveral times, and found always the fame effect. Another remarkable thing happened; I put a piece of common writing paper upon the powder, the chamber being but partly filled, and the fhell went much farther than with the fame charge when there was no paper. Laftly, we compared two chambers of the fame content, the one cylindrical, and the other conical; they had both the fame height, and the diameter of the bottom of the conical one was but half the diameter of

the entrance, and when theſe chambers were not quite full, the cylindric one threw the ſhell much farther than the other, and this happened as often as the experiment was repeated. Whoever conſiders theſe experiments with ſome attention will find, that we know very little of the effects of gunpowder as yet, and that we ought to depend upon nothing but what has been tried.

That our chambers hold a ſufficient quantity of powder, for any occaſion whatever, has been proved by experiments; for I fired a three inch mortar, with an ounce and a quarter of powder, at an angle of elevation of 45 degrees, and the ſhell went 1200 yards; and ſince our mortars are ſimilar to that tried, the powder will give the ſhell the ſame velocity; but becauſe the reſiſtance of the air is in this caſe inverſely as the ſhells diameters, the three inch ſhell will meet above four times the reſiſtance of a thirteen inch ſhell; from whence, and ſome other experiments made upon *Woolwich Common*, with the preſent thirteen inch mortar, I conclude, that the ſhells in our mortar will range about a mile, which is more than is wanted; for when the ranges are greater, they are ſo uncertain, and it is ſo difficult to judge how far the ſhell falls ſhort, or exceeds the diſtance of the object, that it ſerves to no other purpoſe than to throw away the powder and ſhell, without being able to do any execution.

The firſt of theſe mortars is of the ſame length with our land mortars; the ſecond with the *French*; but the third is ſhorter than either. The reader may eaſily ſee, that theſe dimenſions are general for any ſize of mortars whatever, as all conſtructions ought to be, whereby they become all alike; and conſequently one of them being found ſtrong enough by practice or experience, all the reſt will be ſo too; which can never be the caſe in particular conſtructions, as hitherto has been the caſe in all countries ſo far as I know.

To find the weight of metal.

The square of the mean diameter 41 of the muzzle part, multiplied by 30, gives —	50430
The square of the diameter 44 of the reinforce, multiplied by 18, gives —	34848
The square of 34, the chamber part, multiplied by 34 $\frac{1}{3}$, gives — —	39689
Four times the trunion 2940, for the trunions and mouldings — — —	11760
Sum total in cubic parts of the diameter of the bore — — —	136727
The content of the bore in like parts is —	44100
The content of the chamber is —	2033
The two last sums subtracted from the content of the mortar, leaves — —	90594
This reduced in the ratio of 452, to 355, of the square of the diameter to the circle, gives — — —	71152
Then as 192 cubic inches weigh 61 pounds of metal, we get, — —	22605

But as the diameter *d* is divided into 30 equal parts; if we say, as the cube of 30 is to the cube *d*, so is 22605 to the weight of the mortar of the first sort, it will be found to be $\frac{5}{6}d$ nearly. In the same manner are found the weights of metal of the other two mortars.

To find the contents of the chambers.

The square of 10 multiplied by the length, reduced 20 $\frac{1}{3}$, gives 2033 for the first mortar; but as the diameter is divided into 30 equal parts, if we say as the cube of 30 is to the cube *d*, so is 2033 to $\frac{2033}{27000}d$, we get

get the cubic parts of the diameter. Now, becauſe the diameter of a cylinder, which holds one pound of powder, is 3.165, according to Sir *Jonas Moor*, if we divide the laſt number by 31.7, the cube of that diameter, we ſhall have $\frac{2033}{855900}d$, for the content of the chamber; which being reduced, gives $\frac{d}{421}$ or $\frac{d}{531}$ nearly. In the ſame manner are found the contents of the chambers of the other mortars.

In order to compare theſe mortars with thoſe uſed at preſent, we ſhall inſert their weights and charges in the following tables.

Weight of the new mortars.

Diam.	13	10	8	6
Firſt	16 : 1 : 10	7 : 1 : 21	3 : 3 : 6	1 : 2 : 11
Second	13 : 0 : 0	5 : 3 : 22	3 : 0 : 0	1 : 1 : 0
Third	11 : 3 : 0	5 : 1 : 12	2 : 2 : 27	1 : 0 : 15

Weight of the powder.

Diam.	13	10	8	6
Firſt	5 : 3	2 : 6	1 : 3	0 : 8.2
Second	4 : 15	2 : 4	1 : 2	0 : 7.8
Third	4 : 11	2 : [illegible]	[illegible] : 1	0 : 7.4

Weight

Weight of the present mortars.

Diam.	13	10	8	5.8	4.6
Wt.	25:0:0	10:2:18	4:0:10	1:1:0	0:[illegible]:0
Cham.	9:1:8	4:0:0	2:0:10	1:0:0	0:[illegible]:0

Hence if we compare the weights of our mortars with thoſe of the preſent ones, we ſhall find the difference between the 13 inch to be, 8 : 2 : 18; between the 10 inch, 3 : 0 : 15, and between the 8 inch, 0 : 1 : 4. Now as the difference between the weights of the 13 inch mortars, is much greater than between any others, it is evident they are much heavier in proportion than they ought to be, in reſpect of the ſmall ones; it ap[illegible] therefore, that no true proportion has been obſerved in their conſtruction.

Though our mortars are ſo much lighter than the preſent ones, yet I may affirm, they are equally ſtrong; becauſe they are as thick at the chamber as they need be; and at the muzzle, or where the leaſt thickneſs is, ours are ſtronger; for the 8 inch mortar is but an inch in that place, whereas ours is 1 inch and a third; the 10 inch, is 1.6 inches thick, ours $1\frac{2}{3}$; and as to the reinforce, it is loaded with more metal than it need be, ſince the force of powder is very little more there than at the muzzle. But the difference between the weights ariſes chiefly from the chambers, which are both wider and longer in the preſent mortars than in ours, and therefore they require more metal.

General Dimenſions of howitzes. Fig. 11.

Diameter of the bore, —— ——	30	30	30
Length of the bore, —— ——	90	90	97.5
Diameter of the chamber, ——	15	15	15

Length

Length of the chamber, — ——	33	33	33
From the muzzle a, to the reinforce b, —— ——	50	50	54. 5
Length of the reinforce b c, ——	34	34	37
From the reinforce c, to the end of the howitz, —— ——	50	50	50
Total length of the howitz, ——	134	134	141. 5
Thickness of the metal at the muzzle, —— ——	8	7	8
Thickness near the reinforce, ——	9	8	9
Thickness at the reinforce, ——	10	9	10
Thickness at the chamber, ——	16	15	16
Breadth of the muzzle and base ring, fillets included, ———	5	5	5
Breadth of the ogees, that behind the reinforce excepted, ——	3.5	3. 5	3. 5
Distance between the muzzle and breech, ogees and astragals, —	6	6	7
Breadth of the astragals and fillets,	3	3	3
Breadth of the ogee behind the reinforce, —— ——	6	6	6
The muzzle and base ring project the metal by —— ——	1.5	1. 5	1. 5
Length of the trunions — ——	18	18	18
Diameter of the trunions — ——	15	15	15
Distance of the trunions from the fore end of the reinforce, ——	5	5	5
	d	d	d
The chamber contains powder, ——	116	116	116
Weight of the howitz, ——	2.25d	1.97d	2. 4d

The cascable is 24 parts long, the radius of the button 8, the ogee and fillet included 4.

The reader may observe, that for want of room in the plate, the button could not be marked, which he may easily supply from the given dimension in the same manner as in guns.

 The

The dimensions of the first howitz are nearly the same as those of the present, the chamber part excepted; the reinforce is not so strong as it is commonly made, without any ground or reason, because the force of explosion acts but very little more there than at the muzzle. The dimensions of the second are less, and yet I am persuaded sufficient; for a 6 inch howitz is an inch and .4 thick near the muzzle, whereas the present 8 inch mortar is barely an inch in that place; for which reason I would prefer the second sort before the first, because there can be no reason assigned to load them with more metal than is necessary.

The third sort is a quarter of the bore's diameter longer than the other two, and the rest of the dimensions the same as the first; hence the artillerist is left to his choice to use which he likes best.

Weight of the howitzes and powder.

		13	10	8	6
Bore, —		13	10	8	6
Weight	1st,	44 : 0 : 13	20 : 0 : 9	10 : 1 : 0	4 : 1 : 5
	2d,	38 : 2 : 8	17 : 2 : 3	9 : 0 : 0	3 : 2 : 24
	3d,	47 : 0 : 7	21 : 1 : 14	10 : 3 : 13	4 : 2 : 6
Powder,		18 : 15 : 0	8 : 9 : 14	4 : 6 : 9	1 : 13 : 12

Weight of the present howitzes and powder.

Bore, —	10	8	5.8
Weight,	31 : 3 : 26	12 : 1 : 6	4 : 0 : 18
Powder,	18 : 0 : 0	4 : 0 : 0	1 : 0 : 0

From

From these tables of the weights of howitzes, we see that the present 10 inch weighs about one third more than it should do in respect to the 8 inch, for the weights should be in proportion to the cubes of the diameters. Now the cube 512, of 8, is to the cube 1000, of 10, as the weight 12 : 1 : 6, of the 8 inch, is to the weight 24 : 0 : 3, which should be the weight of the 10 inch. Whence it evidently appears, that no better proportions have been followed in constructing howitzes than mortars.

This superfluous weight of the 10 inch howitz has occasioned its disuse, at least these 25 years; whereas by observing a due proportion, and such as our second sort, not only a 10 inch but even a 13 inch might have been used, if it had been thought proper. It may be observed again, that though ours are so much lighter than the others, they are full as strong, because the metal is better disposed over all the parts, and there is not that useless lump at the muzzle, reinforce, and trunions, as in those made at present.

It is to be wondered that no greater use has hitherto been made of howitzes, since the shells may do execution likewise as shots, and besides grapes of shots, or shells, might be fired out of them to more advantage than out of guns, especially in a siege where the distance is but small; and in the field, if they were placed in the flanks, or between the battalions; the terror they would cause, especially amongst the horse, by rolling amongst the ranks with the fuse burning, and the expectation of their bursting every moment, would disorder the bravest men, by means whereof they might easily be broke, and the day thereby won.

In a siege where the works are not lined with walls, or when the walls are once battered down by cannon, there can be no speedier way to complete the breach than by firing shells into them; for they will lodge in the earth, and when they burst will produce the same effect as mines. This practice has been recommended by

St. Remy, and the *French* followed it in the siege of *Bergen-op-zoom*, where they chiefly used mortars, mounted upon field carriages for that purpose; besides, when you are pretty near the enemy's works, grapes made of shells will do wonderful execution, as I have been assured by some artillery officers, who have tried it, and found that all the fuses took fire.

As howitzes are easier carried from one place to another than mortars, which require also a good deal of time to prepare the ground, to lay the beds, and mount them, the use of the former would be more convenient than the latter in all cases, except in throwing shells upon powder magazines. It may be observed, that the wheels and axletree of the present 10 and 8 inch howitz carriages, are of the same strength as those of a 24 and 18 pounder's carriages, without any judgment or reason. For since the wheels of an 18 pounder's carriage support a weight of 48 : 0 : 0, which is just four times the weight of the 8 inch howitz, there is not the least proportion observed between the weight and the strength to support it; it is true, that an 8 inch shell is heavier than an 18 pound ball, but when it is considered that the force of the shell affects the carriage in its recoil only, and not at all the wheels; this can be no reason for making them so strong as has hitherto been the custom.

Of sea mortars.

As these mortars are generally fired at a much greater distance than ever is required by land, they are made something longer and much heavier than the land. Their proper dimensions can only be determined from their charges of powder. The chamber of the present 13 inch holds 32 pounds of powder, though the late General *Borgard* told me, he never made use of more than 12 pounds, and as he had more experience in that service than perhaps any other, we may depend on what

he

he said; besides, some very expert officers employed in the late war assured me, they never exceeded the charge of 15 pounds. Now, as this chamber is never half filled, the powder won't act so forcibly as if there was no vacant space between the charge and the shell; it is therefore plain, that a charge of 12 or 15 pounds of powder at most will be sufficient; besides, this chamber being conical, and its greatest base two thirds of the diameter of the bore, lessens the force of powder considerably, and more so when not filled, as Colonel *Desaguliers* and myself found by several experiments made with such a chamber, and compared with a cylindric one of the same content. This being an undoubted fact, the following dimensions will, I may venture to affirm, be sufficient in all respects.

General dimensions of sea mortars. Fig. 10.

Diameter of the bore divided into — —	30	30
Length of the bore, — — —	75	75
Diameter of the chamber, — —	15	15
Length of the chamber, — —	33	33
From the end of the chamber to the end of the mortar, — — —	20	20
Total length of the mortar, — —	128	128
From the muzzle a, to the the reinforce b,	43	43
Length of the reinforce b c, — — —	28	28
Thickness of the metal at the muzzle, mouldings excepted, — — —	8	7
Thickness of metal near the reinforce, —	9	8
Thickness of metal at the reinforce, —	10	9
Thickness of metal at the chamber, —	16	16
Breadth of the muzzle ring and fillets, —	4	4
Breadth of the ogee next to it, and of that before the reinforce, —	3	3
Distance from the ogee to the muzzle astragal, — — —	6	6

Breadth of the { astragal and fillets, —	3	3
ogee behind the reinforce,	4	4
The muzzle ring projects the metal, by —	1.5	1.5
Diameter of the trunions, — —	18	18
Length of the trunions from the mortar, —	20	20
	d	*d*
The content of the chamber, — —	126	126
Weight of the metal, — —	2.1*d*	1.8*d*

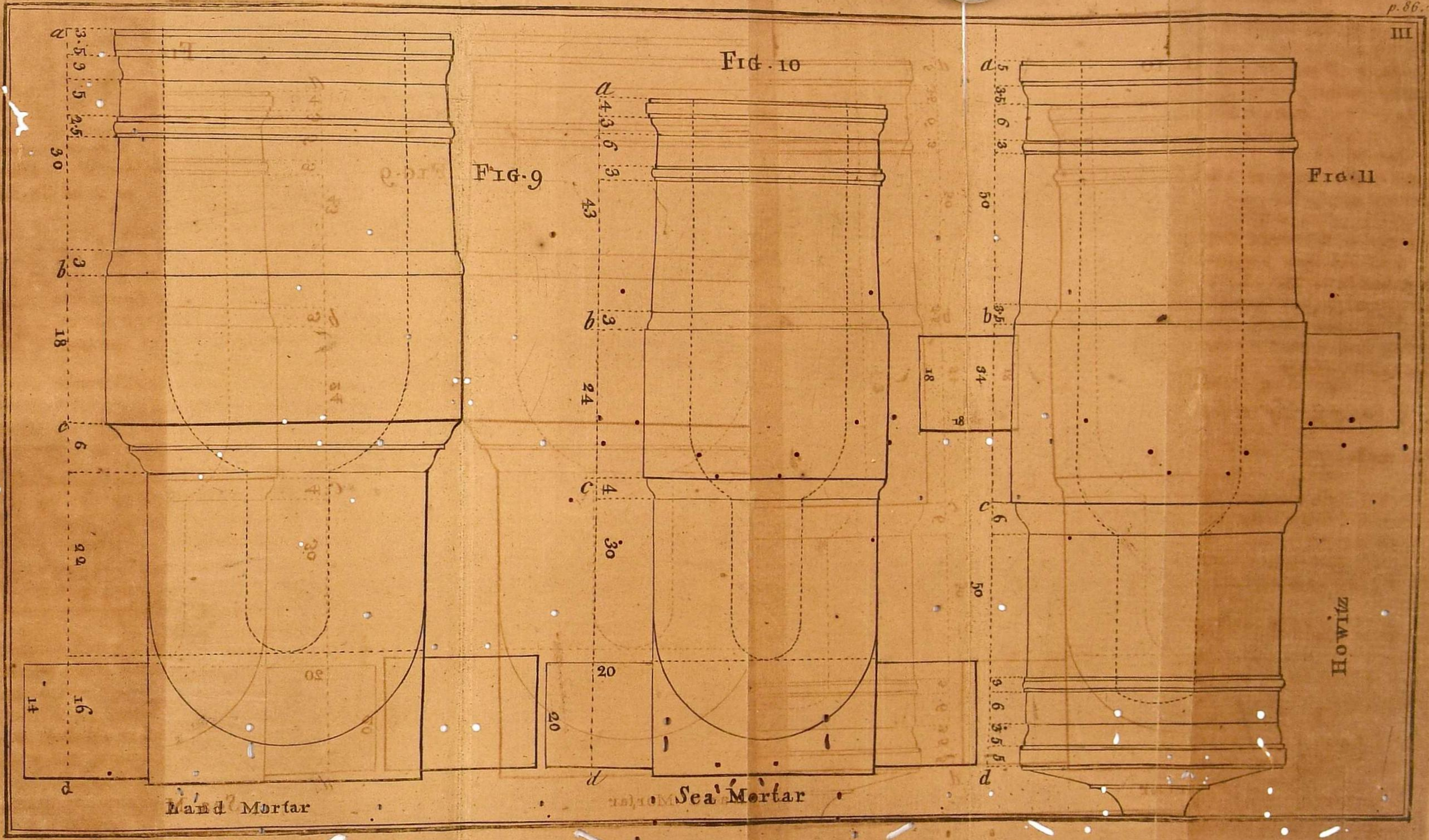
The arcs which determine the round part of the mortar are deſcribed from the ſame center which determines the bottom of the chamber: the weight of metal, and that of the powder which the chamber contains, have been found in the ſame manner as in the guns, allowing four times the value of one trunion for the trunions and mouldings.

Weight of ſea mortars and powder.

Diameter of the bore,	13	10
Weight of { preſent ſea mortars,	81 : 1 : 18	32 : 3 : 7
Weight of { the firſt new mortar,	41 : 0 : 19	18 : 2 : 19
Weight of { the ſecond, —	35 : 1 : 2	16 : 0 : 7
Powd. cont. in { preſent mortars,	32 : 0 : 0	12 : 8 : 0
Powd. cont. in { new mortars, —	17 : 7 : 0	8 : 0 : 0

The enormous weight of the preſent 13 inch mortar proceeds from the antient notion, that thoſe pieces which throw a ſhell fartheſt are the beſt; for which reaſon the artiſt imagined, that the heavier they were, the farther they would carry. But by the account of all thoſe artillery officers whom I have converſed with, and who have been employed in that ſervice, the ſhip or bomb-ketch is not able to bear the ſhock of thoſe mortars, when loaded with their chambers full of powder; and conſequently it is ridiculous to make them ſo heavy.

The


III
Fig. 9
Fig. 10
Fig. 11
Hand Mortar
Sea Mortar
Howitz

The firſt of the new mortars is as ſtrong at the muzzle as the 10 inch preſent one, and conſequently ſtrong enough upon all occaſions; and I may venture to affirm, that the ſecond ſort is ſo too; ſince it is above twice as ſtrong as the land. With regard to the ſize of our chambers, we have ſhewn before, that they never uſe above 15 pounds of powder in bombarding; we have likewiſe proved in the theory of powder, as well as by ſeveral experiments, the great advantage a cylindric chamber has over the conic when the greateſt baſe is uppermoſt, ſo that there cannot remain the leaſt doubt but that our chambers are full as large as they need be on any occaſion.

It may appear ſtrange to ſome of my readers, that mortars ſo much lighter than the preſent ſhould be near equally ſtrong. I account for it in this manner, their chambers are near twice as long as ours, and as the thickneſs is very great in that place, there muſt needs be a great deal more metal there than is neceſſary; the ſame thing may be ſaid with reſpect to the reinforce part, which without any reaſon is made about twice as ſtrong as the muzzle part; though the force of exploſion is nearly the ſame in both places. This was never conſidered in the conſtructions of old mortars.

In the bombarding of *Havre de Grace*, the mortars were fired quick and with a full charge, by which they were ſpoiled and rendered uſeleſs in a ſhort time; for the vents grew ſo large, and the metal melted in the chambers, that it would have been dangerous to fire them any more, and ſo were rendered entirely uſeleſs.

It has been obſerved both in guns and mortars, that the great thickneſs of metal, inſtead of being an advantage, renders them ſooner uſeleſs. For at the battle at *Lafeldt* ſeveral 6 pounders, that weighed 1900, were ſpoiled, and the light, which weighed but 4 : 3 : 0, received no damage; and our ſea mortars generally fail when much fired with great charges; whereas the land, which do not weigh one third of the others,

ſcarcely

ſcarcely ever fail: the reaſon of this is imagined to be, that thin metal heats not imperceptibly ſooner than thicker, and cools much ſooner; and when thick metal is once much heated requires a longer time in loading, and conſequently accumulates the heat to ſuch a degree as to make it incapable to reſiſt the ſhock of the fire. This is confirmed by experience.

Plate IV. Fig. 12.

The following mortar with a concave chamber is, I think, preferable to the two former; the baſe a b, or c d, is ten parts; the diſtance between the lines a b, and c d, is 26 parts; and its greateſt tranſverſe diameter 20; the thickneſs of metal at the chamber is 16 parts, as before; the outſide form is ſimilar to that of the chamber, and all the other dimenſions are the ſame as thoſe of the firſt of the two preceding mortars. This mortar will weigh nearly as much, and its chamber contain the ſame quantity of powder as the firſt; but as the entrance of it is to that of the former, as 4 to 9, the powder will act with a greater force; for which reaſon it is preferable.

As the entrance is wide enough to introduce the hand, and clean it without any inconveniency, it may be loaded with as much eaſe as any other; whereby we avoid the objection made by ſome againſt theſe kinds of chambers.

As to the placing the vent both in guns and mortars in the beſt manner, I muſt confeſs it is beyond my knowledge; and it appears to me, that nothing but experiments can determine it; for thoſe I made with two ſmall mortars appear ſo contradictory to theory, and the notion we have in reſpect to the exploſion of powder, that I am more uncertain than ever; and it is very probable they will vary more in thoſe of larger calibers, for which reaſon we leave it undetermined. I ſuppoſe it, in all the preceding draughts, pretty near the end of the chamber;

chamber; becauſe the few experiments I made ſhewed that to be the beſt place in ſmall mortars.

SHELLS. Plate IV. Fig. 14.

As the dimenſions of ſhells are undetermined, and no proportion obſerved therein, nor is it known how much the thickneſs of the bottom ought to exceed that at the fuſe hole, ſo as they may burſt in the greateſt number of pieces, we have in the following dimenſions obſerved the proportions of the preſent 13 inch ones; ſo that if they are right, we are certain that ours will be ſo too; but if it ſhould ſo happen, that the ſhell of any other caliber is found to have a better proportion than that we have made uſe of, the general dimenſions may eaſily be made in the ſame proportion, by ſaying, the diameter of the ſhell is to 30, as any part expreſſed in inches, is to the ſame part, expreſſed in parts of the diameter divided into 30 equal parts.

Diameter	of the bore, — —	30
	c d of the ſhell, — —	29.5
	of the hollow ſphere, — —	21
Thickneſs	of metal at the fuſe hole, —	3.5
	at the bottom or oppoſite part —	5
Diameter a b of the fuſe hole,	— —	4
		d
The weight of the ſhell unloaded,	—	11.7
Weight of the powder the ſhell contains	—	236.5

The fuſe hole is conical, and when produced, terminates at the extremity d of the diameter c d, which paſſes through the center.

There are two handles of hammered iron fixed in the mould when they are caſt, which faſten to the ſhell, and ſerve to lay hold on when the mortar is to be loaded thereby, as likewiſe to carry them from one place to another.

other. In *France* these handles are cast iron; but this renders them clumsier, and liable to break sooner than the others. The letter *d* stands here for the cube of the diameter of the bore, as well as in the construction of mortars.

Two reasons are given for making shells thicker at the bottom than at the fuse hole; one is, that they are thereby better enabled to resist the shock or impression of the powder that discharges them; the second, that the shell always falling with the heaviest part undermost, the fuse will of course be uppermost, and therefore will not be extinguished by its fall. Both these reasons are, in my opinion, of no consequence; for if the shells were every-where equally thick, and of the same weight as those above-mentioned, the blast of powder lodged in the chamber would hardly be able to break them; and as to the fuse falling uppermost or not, that is of no detriment, since the composition of fuses is such, that nothing but an absolute stoppage from the air is able to choak them; for they burn in water as well as any other element; for which reason I would make them every where equally thick, because they would then burst into a greater number of pieces. But to be certain, it would be easy to make the experiment.

The quantity of powder they ought to be filled with, so as to burst into most pieces, is not known; but most artillerists agree that they should not be quite full; and Colonel *Desaguliers*, after having made several experiments, imagines, that two thirds of the weight which would fill them is the quantity they should be loaded with.

Weights of the present shells and powder.

Bore,	13	10	8	5. 8	4. 6
Wt.	1 : 2 : 15	0 : 2 : 25	0 : 1 : 15	0 : 0 : 12	0 : 0 : 7
Powd.	9 : 4 : 8	4 : 14 : 12	2 : 3 : 8	1 : 1 : 8	0 : 8 : 0

Weight

Weights of the new ſhells and powder.

Bore,	13	10	8	5.8	4.6
Wt.	1 : 2 : 15	0 : 2 : 27	0 : 1 : 14	0 : 0 : 16	0 : 0 : 8
Powd.	9 : 4 : 8	4 : 3 : 10	2 : 2 : 10	0 : 13 : 3	0 : 6 : 9

It is to be obſerved, that the windage of the preſent ſhells is a quarter of an inch, let them be great or ſmall, which is contrary to all reaſon; whereas we allow $\frac{1}{60}$ part of the bore's diameter, which is ſomething leſs in a 13 inch one, and decreaſes in proportion to the ſhell's diameter; whereby our ſmall ſhells become ſomething heavier than the preſent.

There is another kind of mortar which ſerves to fling ſtones into an enemy's works, when near at hand; ſuch as from the town into the trenches in the covert way, or upon the glacis, and from theſe trenches into the town, or ravelins. As we have none of that ſort here, I ſhall give ſuch dimenſions as agree nearly with thoſe mentioned in *St. Remy*, whoſe diameter is 15 inches.

Dimenſions of ſtone mortars. Fig. 13.

Diameter of the bore,	30
Length of the bore,	37
Length of the chamber,	16
Its greateſt diameter	8
Its leaſt diameter,	6
Diameter of the cylindric part to hold a wooden tapeon,	14
Depth or axis of that cylinder,	3
From the muzzle to the reinforce	20.5
Length of the reinforce	8

Thickneſs

Thickneſs of the metal at the	muzzle, — —	3.5
	reinforce, ——	4.5
	chamber belt,—	9
	entrance of the chamber, —	6
The chamber enters into the trunions, by —		2
Diameter of the trunions, —— ——		40
Length from end to end of the trunions, ——		40
Breadth of the	muzzle ring and fillets, ——	3
	chamber belt, — — —	2
	ogee next to this belt, —	3
		d
Content of the chamber, ——		1102
Weight of the metal contained in this mortar,		3.1

The bore is terminated by two quadrants of a circle, terminated by the reinforce and lines drawn from the ends of the cylinder made to lodge the tapeon parallel to the axis of the mortar; and the round part on the outſide are arcs deſcribed from centers, taken in the line which terminates the reinforce, and ſo as to meet the extremities of the belt. The bottom of the conic chamber is terminated by an arc of 60 degrees, and the round part of the outſide is a ſemicircle.

Thus a 15 inch ſtone mortar weighs 10 : 3 : 4, and the chamber contains 3 pounds of powder; this agrees very nearly with the *French* mortar of the ſame ſize, which weigh 1000 pounds. When it is conſidered that we made the chamber part ſtronger than theirs, we conceive that this mortar may likewiſe ſerve to throw baſkets full of hand-grenades, which will be much more dangerous to an enemy than ſtones.

The reader may eaſily perceive, that the conic chamber is very proper here in this caſe, as a great force is not ſo much required as the extent of that force againſt the tapeon, for fear it might break it in the middle.

The

Sea Mortar
With a Concave Chamber.

Stone Mortar

Fig. 12

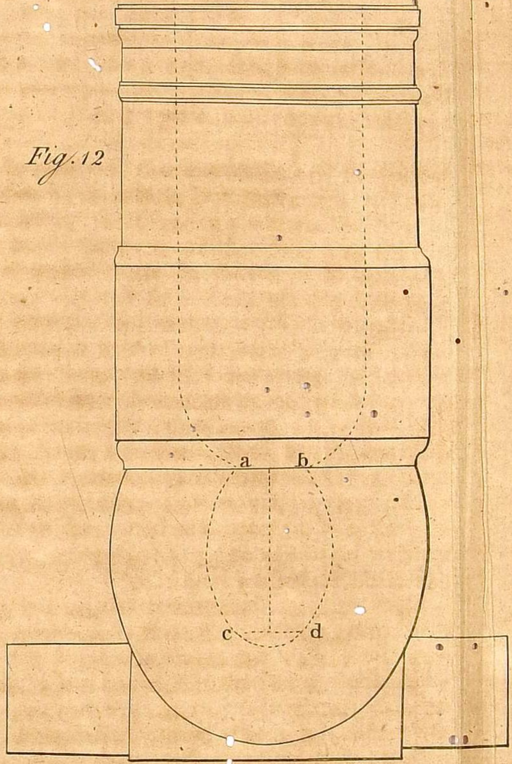
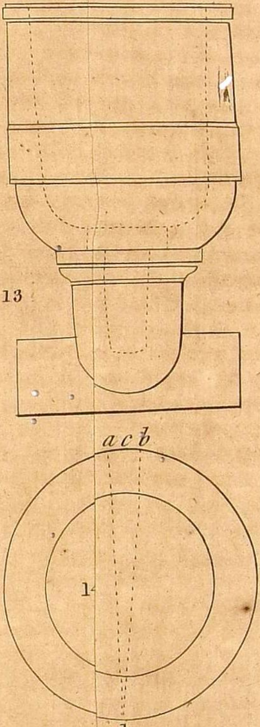


Fig 13



The form of the bore at the bottom being different from that in other mortars, is likewiſe adapted here to the bodies to be thrown out of it; baſkets are made to fit the bottom of the bore, which, when filled, are let into the mortar by means of two handles, in order to load it quicker. The ſtones generally made uſe of upon this occaſion are pebbles the bigneſs of a man's fiſt, and as round as can be found. But as we ſaid before, hand-grenades or ſmall ſhells made for that purpoſe, of about two or two and a half inches diameter, will anſwer the purpoſe much better than ſtones. This has been practiſed at *Bergen-op-zoom* with a common mortar, and ſucceeded to the ſatisfaction of the artillery officers who tried the experiment.

Having thus given general conſtructions for mortars uſed on all different occaſions either by ſea or land, it remains to ſhew in what the uſe of howitzes differs from that of common mortars; as they are carried upon gun travelling carriages, they are eaſily tranſported in the field from one place to another, and are more readily fired than the others; they have likewiſe another advantage, which is, that they may be laid to any elevation, whereas the common mortars are fixed upon their beds at an angle of 45 degrees, whereby they are not ſo uſeful in a ſiege: for the ſhells thrown into the works, either from the trenches into the fortification, or from the fortification into the trenches, ſhould always be directed in a leſs elevation than 45; and when they are to be thrown upon powder magazines, or any other building, with an intention to deſtroy it, the elevation ſhould be greater, in order that they may fall with more force.

All theſe conſiderations are ſeeming advantages in favour of the howitzes; but if we conſider that a 10 inch howitz weighs conſiderably more than a 13 inch mortar, and an 8 inch one more than a 10 inch mortar, it is eaſily perceived that the uſe of howitzes is not ſo ſuperior to that of the common mortars as is imagined by moſt artilleriſts. As to the different degrees of elevations in which

which they may be directed, it is a property that mortars ought to have as well as they. For there is not the leaſt occaſion to fix them on their beds ſo as not to be moved, ſince no nation but this does it; nor to laſh them on their beds with ſo much cordage, as if their weight was not ſufficient to keep them in their ſituation. The reaſon given for this practice is, that if they were not laſhed to their beds they would kick up before, and fall backwards, which is trifling, and inconſiſtent with the rules of mechanics; beſides the *French* mortars, which are much lighter than ours, and are not tied, never overſet; and as no nation makes more uſe of them than they do, it is very improbable they ſhould neglect a thing of that kind if there was any neceſſity for it.

As to the advantage of carrying howitzes upon travelling carriages, it is as inſignificant as the reſt, ſince no reaſon can be given why mortars may not be carried in the ſame manner. That this may be done, appears from the practice of the *French* during the laſt war. But what will not people do to ſupport an old cuſtom let it be ever ſo abſurd?

PART IV.

Conſtruction of ſhip and travelling carriages.

THERE are three different ſorts of gun carriages; namely, thoſe uſed in garriſons, at ſea aboard ſhips, and in the field. The two firſt differ only in ſome iron rings, and alſo that the trucks or wheels of garriſon carriages are made of caſt iron; whereas ſhip carriages are of wood; but the reſt of the conſtruction is the ſame.

Construction of ship and garrison carriages.

Plate V. Fig. 15.

In a line A B, take two points C, D, so as their interval be equal to the distance from the center of the trunions to the extremity of the breech, that is, equal to three sevenths of the gun's length; through these points draw two lines at right angles to A B; in the first take C E, C F, each equal to half the diameter of the second reinforce ring; and in the second D G, D H, each equal to half the diameter of the base ring; then the lines drawn through the points E, G, and F, H, will determine the width within of the carriage.

If to these lines there be drawn two parallels at a caliber's distance, they will determine the breadth of the side pieces; and by setting off from D to B, the length of the cascable, and from C to A, half the diameter of the trunions and half the diameter of the fore trucks; then will A B be the length of the carriage.

The line E F passes through the center of the trunion holes, which are a caliber, and whose center is a quarter of an inch below the upper surface of the side pieces. On each side of G H set off 6 inches for the breadth of the axletree, which is always 12 inches broad; and the fore part of the trunion holes is the center line of the fore axletree, whose dimensions, as well as those of the trucks, are given in the following table.

Fig. 16.

The height of the side pieces is 4¾ diameters of the shot before, and half that height behind; and if half the length of the side pieces be divided into four equal parts, beginning at the hind end, you will have the steps; the quarter-round is taken from the fore part. The lower part of these pieces is hollowed in the form of

of a circular arc, in order to make them something lighter without diminishing their strength. Both axletrees are sunk into the side pieces in the manner represented in the 17th figure; and as to the transom, we chuse to place it directly over the fore axletree, it is a diameter of the shot broad and two high, and placed exactly in the middle of the height of the side pieces; though it is customary to place the fore part in a line passing through the center of the trunion holes, and so as to project the axletree by an inch, and the lower edge to touch the axletree.

Dimensions of ship and garrison carriages.

Nature of the gun,	42	32	24	18	12	9	6	3
Width inclosed { before	18	18	16.5	15.5	14	13	11.5	9
Width inclosed { behind	23.5	23.5	22.5	21.5	19.5	18.5	16.8	12.5
Fore axletree length	57	57	54.5	51.5	45.5	42.5	38.8	32.5
Body { length,	35.4	36.6	34.9	33.1	29.5	27.5	24.8	19.5
Body { height,	10.8	10.8	10.	10	10	9.5	9	8.5
Body { breadth,	6.8	6.8	6.8	6	5.5	5.2	5	4
Arms { length,	10.8	10.2	9.8	9.2	8	7.5	7	6.5
Arms { diameter,	6.2	6.2	6.2	5.8	5.2	5	4.5	3.5
Hind axletree length,	57	57	54	51.5	45.5	42.5	38.8	32.5
Body { length,	35.4	36.6	34.9	33.1	29.5	27.5	24.8	19.5
Body { height,	6.8	6.8	6.8	6	5.5	5.2	5	4
Body { breadth,	12	12	12	12	12	12	12	12
Fore trucks, { diameter,	19	19	18	18	16	16	14	14
Fore trucks, { breadth,	6.5	6	5.5	5	4.5	4	3.5	3
Hind trucks, { diameter,	16	16	16	15	14	14	12	10
Hind trucks, { breadth,	6.5	6	5.5	5	4.5	4	3.5	3
Side pieces { height before,	26.8	26.2	26	23.6	20	18.8	16	13.6
Side pieces { length,	78	78	72	69	66	63	60	37.5
Side pieces { breadth,	6.5	6	5.5	5	4.5	4	3.5	3
Trunions from the head,	8	8	8	8	6.8	6.6	6.6	6

These

These dimensions are expressed in inches and decimals; and as the arms of the hind axle-tree have the same dimensions as those of the fore ones, they have been omitted, as well as the height behind the side pieces.

It may be observed, that these dimensions were used in 1748; but if the guns are made different from those at that time, the length and width of the carriages will likewise differ. The height of the side pieces and the diameter of the trucks depend on the height of the port-holes in ships from the deck. Those of the lower tiers ought to be such, that when the breech of a gun lies upon the hind axle-tree, the muzzle of the gun should touch above the port-hole, in order that it may not push the shutter open when the ship rolls in stormy weather.

General construction of carriages for new guns.

We suppose the diameter of the shot to be divided into 24 equal parts, as in the construction of the gun, so that the guns and their carriages may be constructed by the same scale; which is both more methodical and easier for the reader and the artillerest.

This being supposed; take C D equal to 6 diameters of the shot and 10 parts; and C E, C F, each equal to 34 parts, as likewise D G, D H, each equal to 39.5; the breadth of the side pieces is a diameter or 24 parts; D B to a diameter and 12 parts; A C to 2.5 diameters. The breadth of the fore axle-tree is 30 parts, its length $6\frac{1}{3}$ diameters; the length of the arms 44 parts, and their diameter 24. In the elevation, the height before of the side pieces is $4\frac{3}{4}$ diameters, and behind half that height; the height of the fore axle-tree is 42 parts, that of the hind one 30; the bed bolt passes under the middle of the fourth step, and even with the last or hind step.

The breadth of the wooden trucks is always equal to that of the side pieces, which is here one diameter or 24 parts; the diameter of the fore ones 4 diameters, and

and that of the hind 3 diameters and a half: but we have obſerved before, that if the port-holes in ſhips are made higher or lower, theſe diameters muſt be increaſed or diminiſhed.

The *French* make uſe of a carriage on board of ſhips with two trucks before only, and are preferred by many officers to thoſe of 4: I had ſome of them made, which ſeem to anſwer very well; they are nearly of the ſame height before as the common; but to leſſen the great height of the ſide pieces, the trucks are made of a larger diameter; they have no ſteps, and behind have a tranſom for the ſtool-bed to reſt upon inſtead of the body of the hind axle-tree. Theſe carriages do not recoil ſo much, and are more readily pointed, becauſe the trucks are not tight to their axle-tree. When they are traverſed but a little, the carriage will move without the truck, and then fall back again ſo ſoon as the hand-ſpike is taken away.

The *French* garriſon carriages are made much in the ſame manner; but the trucks are made larger and of ſeveral pieces, and have a trail like travelling carriages, but much ſhorter.

Fig. 17.

This elevation ſhews the inſide of the ſide pieces, with ſome of the irons, not elſe to be ſeen, and the manner we would have the ſide pieces let into the axle-trees, which is more ſimple, and yet equally as ſecure as the common manner, as likewiſe how the tranſom is to be placed, and not obliquely as the cuſtom is. The reſt of the figures in this plate ſhew the plans and elevations of the axle-trees and the ſtool-bed, as well as the tranſom.

Iron

Irons for ſhip carriages.

a. Cape ſquares,	2
b. Eye bolts,	2
c. Joint bolts,	2
d. Tranſom bolt,	1
e. Bed bolt,	1
f. Bracket bolts,	2
g. Hind axle-tree bolts,	4
h. Breeching bolts with rings,	2
k. Burrs,	2
l. Loops,	6
m. Dowel pins,	4
n. Square rivetting plates,	8
p. Rings with keys,	10
q. Traverſing plates,	2
r. Linch pins,	4
s. Axle-tree hoops,	2
t. Axle-tree ſtays,	2
w. Keys, chains, and ſtaples,	2
x. Stool bed bolts with rivetting plates,	2

The garriſon carriages have the ſame irons, excepting the breech rings, and their trucks are of caſt iron; for which reaſon their axle-trees have copper clouts underneath, to diminiſh the friction of the iron againſt the wood.

Of travelling carriages. Plate VI. Fig. 19.

Previous to their conſtructions, it is neceſſary to mention the names of the ſeveral parts they are compoſed of, which are as follows. The long ſide pieces Q P, R S, are called the Cheeks; the fore part Q R of the carriage, the Breaſt; and the hind part P S, the Trail; T, the Trail Tranſom; V, the Center Tranſom; X, the Bed Tranſom; and Y, Breaſt Tranſom; G H, the

Body of the Axletree; m, n, the Trunion Holes; and w, the Pintle Hole.

Dimensions of the present cheeks.

Nature of the gun,	24	12	6	3
Length of the cheeks,	13	12	11	10
Thickness,	5. 8	4. 6	3. 6	3
Height of the plank,	22	19	16	13
Height of the cheek — before,	20	17	14	11. 5
Height of the cheek — center,	17	15	12	9. 5
Height of the cheek — trail,	12	11	10	7. 5
Head from the center,	74	69	60	51. 5
Length of the trail,	18	15	12	10

Axle-trees.

Nature of the gun,	24.	12.	6	3
Body, — length,	38. 5	39	40	40. 5
Body, — breadth,	7	6. 5	6	5. 5
Body, — height,	9	8. 5	8	7. 5
Arms, — length,	21	20. 5	19	17. 5
Arms, — body diameter,	7	6. 5	6	5. 5
Arms, — linch diameter,	5	4. 5	4	3. 5
Total length	81	80	78	76

N. B. The under part of the axletree should be in one continued right line, as we have shewn in our *Elements of Mathematics.*

All the dimensions in the preceding tables are in inches and decimals, except the length of the cheeks, which are in feet.

Construction of travelling Carriages. Plate VI. Fig. 18.

Let A b c d be the plank, and A B the height before of the cheeks; set off from B to C the sum of the head A B, and the distance from the hind part of the trunions

Pl: V.

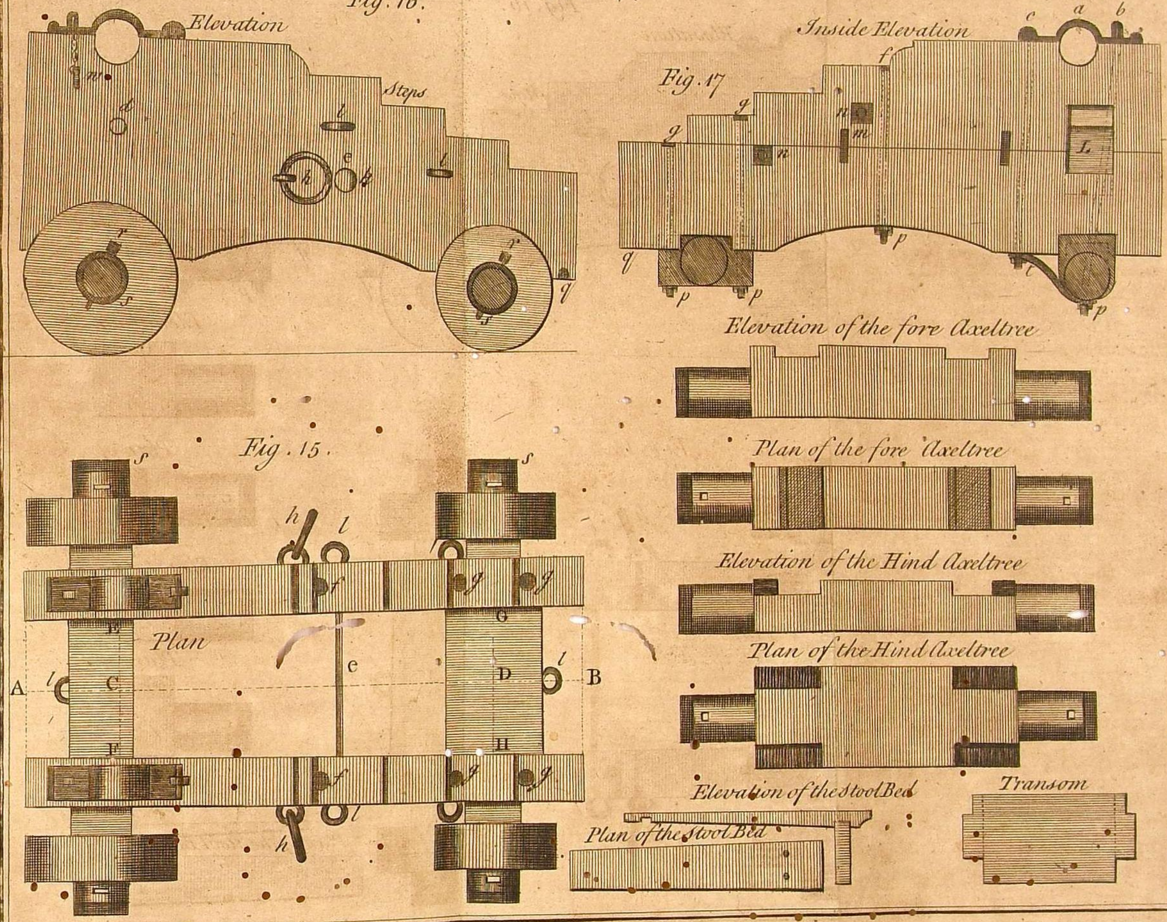


Fig. 16.
Elevation
Steps
Fig. 17
Inside Elevation
Elevation of the fore Axeltree
Plan of the fore Axeltree
Fig. 15.
Plan
Elevation of the Hind Axeltree
Plan of the Hind Axeltree
Elevation of the Stool Bed
Plan of the Stool Bed
Transom

trunions to the extremity of the cascable; then from the point A as center, describe an arc C D through the point C, on which as a chord set off the height at the center, and draw the lines AD, BC. On BC take BE, equal to the head A B, and towards the head E r, r S, each equal to half the diameter of the trunions, so that E S will be the width of the trunion hole, whose center is about a quarter of an inch below the line B C. From the point r draw r F, perpendicular to A D; in A D take F H, equal to the breadth of the axle-tree which is sunk about an inch into the cheeks. On the side F H make a square, and from the intersection I of diagonals, as center, describe an arc, with a radius of 29 inches, or equal to the radius of the wheel; this arc will represent a part of the wheel. Then if a ruler be laid so as to touch this arc, and cut the plank in two points M, L, such that the distance M L be equal to the length of the trail, and you erect at these points two perpendiculars M N, L O, to K M, each equal to the height of the trail; by drawing the lines C N, N O and D M, you will have the figure A B C N O L D A of the cheek required.

The part M P is made round, that the carriage may slide with more ease on the ground, which is done by dividing L O into four equal parts, so that L P be one of them, by drawing M P; and at the points M and P erecting two perpendiculars on D M, and on M P which meeting in Q, then the point R, which bisects M Q, will be the center of the arc M P required.

The mortise V of the center transom is determined by drawing a line through the point C, perpendicular to the horizon K M, in which C p is taken equal to a fourth part of the shot's diameter, and p q equal to two of these diameters for the height, and in p z, parallel to K M, the breadth p x equal to one diameter. The distance between the center and bed transom X is two diameters; this last is a diameter each way. The breadth of the transom Y is a diameter broad and two high; the si

re parallel to the head A B, and terminate above even vith the bottom of the trunion hole one way, and when produced the inside meets the point S. Lastly, the morise T of the trail transom is equal in length to the trail, diameter high, and is parallel to the upper side N O, o as when the lower is produced to meet the point P.

All these mortises are divided into four equal parts by orizontal lines; the upper part is sunk half an inch ino the cheeks; the two middle parts are sunk to the epth of two thirds of the thickness of the cheeks, but he lower part is not sunk in at all. They are made in his manner to prevent the wet from getting into the oint and rotting the tenons.

Construction of the plan. Fig. 19.

Draw the indefinite line A B, in which take the points , D, so as their interval be equal to the distance from e center of the trunions to the extremity of the base ng; through these points draw E F, K L, at right gles, to A B; make D K, D L, each equal to the dius of the base ring, and C E, C F, each equal to e radius of the second reinforce ring; then the lines awn through the points F, L, and E, K, will deterine the width within of the carriage; if to these lines o others are drawn parallel, and at a distance equal to e length of the trunions, you will have the thickness the cheeks Q r and R S.

On both sides of the points E and F, set off half the ameter of the trunions, in order to have the trunion les m, n; draw the breast transom Y of a diameter oad, so as the inside be in a line with the fore part the trunion holes; and if C A be taken equal to r B the last figure, the line R Q at right angles to A B ll determine the breast of the carriage, and the total gth A B of the carriage is determined by the last ure,

If

If you set off from the line K L two diameters for the length of the cascable, you will have the hind part of the center transom V, whose width is a diameter as well as the bed transom X, and their interval is two of these diameters, as has been said before; the trail transom T is determined as before by the length of the trail. In the middle of this transom is the pintle hole of an oval figure, wider above than below, that the pintle may have room to play on uneven ground.

The bed w is a board of an inch and a half thick, a foot broad, and sunk into the bed and center transoms; the width of the axle-tree has been determined before, and its fore part passes through the centers of the trunion holes: there is a board fixed upon the axle-tree with one end, and the other upon the bed transom, which serves to lay hay or straw upon for wadding.

Between the trail and center the breadth of the cheeks is diminished on the inside by a sixth part, beginning at about a diameter from the trail, and ends within a diameter and a half from the center transom.

This is the common construction of field carriages; but as it relates only to the four calibers, whose dimensions have been given, the reader will still be at a loss how to construct any other; and as the length of the cheeks depends not only on the caliber of the gun, but likewise on the height of the wheels, as well as on the length of the pieces, which varies very often: therefore, in the following construction, we suppose the wheels of the common size, and the guns to be 20 or 21 diameters long, which is the common length at present of the 24 pounders.

General dimensions of travelling carriages. Fig. 18.

The length A d of the plank is 12 diameters of the shot and 7.5 feet besides; its height A b three diameters and three quarters; the height A B of the cheeks three diameters and a quarter; so that B b is half a diameter, the

 height

height D C at the center 70 parts of that diameter, divided into 24 equal parts, as in the conſtruction of guns; the length of the trail is three diameters, and its height M N two; the breadth F H of the axle-tree is two diameters, and the reſt of the dimenſions depend on the ſize of the gun.

General conſtruction of travelling carriages for the new guns.

Plate VI. Fig. 18.

The length A d of the plank is 10 diameters of the ſhot and 7.5 feet; its height A b, three diameters and three quarters; the height A b of the cheeks, three diameters and a quarter. Set off from B to C eight diameters, and twenty parts of that diameter divided into 24, as in the conſtruction of guns; then from the point A, as center, deſcribe an arc through the point C, on which, as a chord, ſet off 70 parts from C to D, and draw the lines A D, B C. On B C take B E, equal to the head A B, and towards the point B, the parts E r, r S, each equal to 9 parts, ſo that E S will be the width of the trunion holes, whoſe center is ſunk about a quarter of an inch into the cheek. From the point r draw r F, perpendicular to A D, and in A D take F H, equal to 30 parts for the breadth of the axle-tree, which is ſunk into the cheek about an inch. On the ſide F H make a ſquare, and from the interſection I of the diagonals, as center, deſcribe an arc with a radius of 29 inches, which arc will repreſent a part of the wheel. Now if a ruler be laid ſo as to touch this arc, and cut the plank in two points M, L, ſo that the diſtance M L be equal to three diameters, and there be erected at theſe points the perpendiculars M N, L O, to K M, each equal to two diameters, then, by drawing the lines C N, N O, and D M, you will have the outline A B C L D A of the cheeks. The under part of the trail is made round,

round, and the mortiſes of the tranſoms are made as before.

Conſtruction of the plan. Fig. 19.

Draw the indefinite line A B, in which take the points C, D, ſo as their interval be 7 diameters and 17 parts; through theſe points draw E F, K L at right angles to A B; make D K, D L, each equal to 32.5 parts, and C E, C F, each equal to 27.5 parts; then the lines drawn through the points F, L, and E, K, will determine the width within of the carriage. If to theſe lines two others are drawn parallel, and at 18 parts diſtant, you will have the thickneſs of the cheeks, Q P and R S.

On both ſides of the points E F, ſet off 9 parts for the radius of the trunions, in order to have the trunion holes m, n. If C A be taken equal to r B in the laſt figure; the line R Q, drawn at right angles to A B, will determine the breaſt of the carriage, and the total length A B is determined by the laſt figure. The reſt of the conſtruction is the ſame as before.

Remarks on this conſtruction.

Regard muſt be had in the conſtruction of theſe carriages to their ſtrength, and that the piece may lay cloſe and ſteady in it; as likewiſe that the gun may be properly elevated, in caſe ricochet firing ſhould be required.

The thickneſs of the cheeks are here ſuppoſed eighteen parts inſtead of a caliber, as is uſual; this we eſteem ſufficient, becauſe pieces are now loaded with no more than one third of their ſhot's weight, or ought not at leaſt; which charge has been found ſufficient for battering pieces.

The length of theſe carriages is ſuch, that a 24 pounder may be elevated to about an angle of 9 degrees, and

and the ſmaller ones to 10, or 11 and 12, which is more than ſufficient upon all occaſions. The cheeks are not bent too much at the center, becauſe, if they are, they become very weak in that part. We make the trunion holes ſo as one half of them is over the axle-tree, whereas the common practice is to make them juſt without, which, in my opinion, occaſions the weight of metal to hang too much beyond the center of the wheels.

Plate VII. VIII.

In theſe plates are the plan and elevation of a 6 pounder travelling carriage, with all the irons marked on them, ſuch as are now made.

Iron-work of travelling carriages.

Tranſom bolts with burrs	breaſt	1
	center	2
	trail	2
Tranſom plates with hooks	breaſt	2
	center	2
	trail	2
Trunion plates		2
Cap ſquares with joint bolts		2
Spring keys with chains and ſtaples		4
Eye bolts	fore	2
	hind	2
Breaſt plates		2
Plates with roſes	garniſh	2
	trail	2
Garniſh	bolts	2
	nails	6
Axle-tree bands		2
Side ſtraps		4
Draught rings with bolts and burrs		2
Locking plates		2
Laſhing rings with loops		8

VI

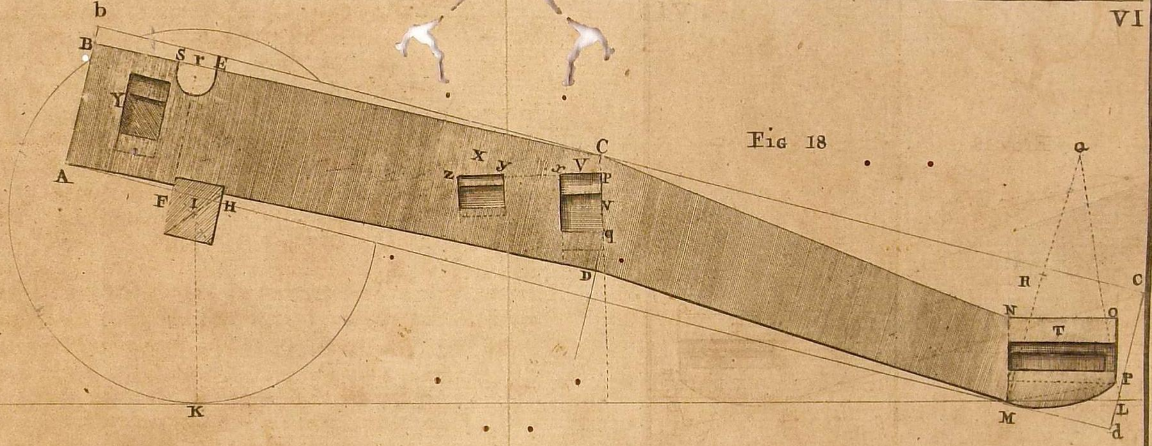


Fig 18

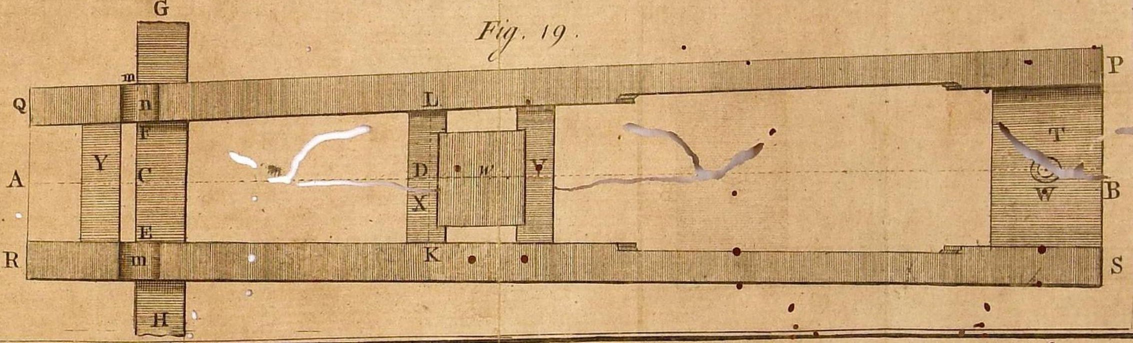


Fig. 19.

Single forelock keys	——		——	8
Bed piece chain with ftaple		——	——	1
Locker { hinges	——	——	——	2
Locker { hafp with ftaples		——	——	1
Wood fcrews				
Rivets				
Nails { rofebuds				
Nails { diamond headed				
Nails { counterfunk				
Nails { trail				
Pintle plates upper and under		——	——	1

Names of the parts of a wheel. Plate IX.

A. Nave	——	——	——	1
B. Spokes	——	——	——	12
C. Fellies	——	——	——	6
n. Dowel pins	——	——	——	6
a. Streaks	——	——	——	6
b. Streak nails	——	——	——	48
c. Nave hoops	——	——	——	3
d. Nave boxes	——	——	——	2
f. Dowledges	——	——	——	6
g. Rivets for ditto	——	——	——	24
h. Nave hoop ftubs		——	——	9
k. Box pins	——	——	——	6

The dowel pins are wooden pegs, of about three inches long, and three quarters of an inch in diameter; they ferve to faften the fellows together; and the dowledges are iron plates, faftened and funk into the fellies on the outfide, fo are not feen here; they ferve to bind the joints of the fellies ftrongly together, each with four pins.

The nave is always made of elm, cut fix months before it is ufed, and left in the bark all the while till it is ufed; the fpokes are made of elm or young oak, and ufed as dry and well feafoned as poffible; the fellies are likewife

likewiſe made of dry elm, or in default of which young beech ſplit in two only will do as well, if not better; and the axle-tree is made of dry elm, young oak, or young beech.

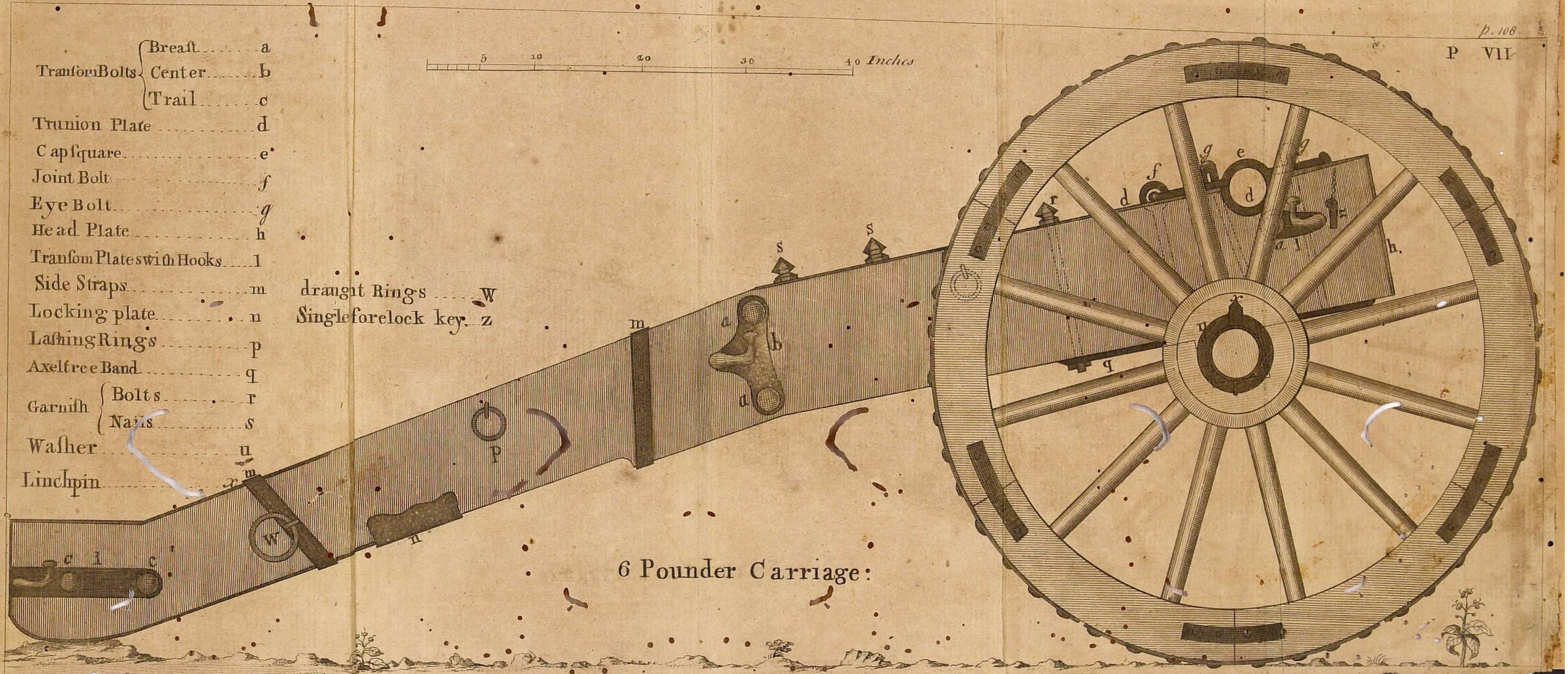
The cheeks and tranſoms are always made of dry elm, on account that this wood is very pliable, receives the nails better than any other, and does not ſplit; yet I have ſeen ſome made of young oak, and am of opinion it is much ſtronger than elm, and I think may anſwer better.

Dimenſions of wheels for travelling carriages.

Caliber	24	22	6	3	Parts
Wheel, diam. inches	58	58	58	58	
Nave, length	17. 5	17	15. 5	15	76
Diameter, body	15	15	13	12. 5	62
Diameter, middle	16	16	14	13	74
Diameter, linch	13. 5	13. 5	10	10	60
Fellies, thickneſs	5	4. 5	4	3	22
Fellies, breadth	6. 5	6	5. 5	4. 5	28
Spokes, thickneſs	2. 3	2. 2	2. 1	2	10
Spokes, breadth	4. 5	4	3. 5	3	20

The mortiſes of the ſpokes ſhould be placed in the middle of the nave, but the workmen make them an inch nearer to the linch. The ſpokes are ſomewhat leſs near the fellows than at the nave; they are likewiſe inclined towards the linch three inches in a wheel five feet high, and ſo in proportion in one of any other diameter; which the workmen call *diſhing*. How they found out that this inclination renders the wheels more perfect is not eaſily known; thoſe that I have converſed with knew no more than that it was an old cuſtom, which made me inquire farther into it, and I have found that it is grounded on true mechanical principles, as may be ſeen in my *Elements of Mathematics*, page 245.

The



6 Pounder Carriage:

The laſt column in the preceding table contains the general dimenſions of the reſpective parts for wheels of any ſuch carriages, expreſſed by the parts of the diameter of the ſhot divided into 24, as in the conſtruction of guns, and proportional to the dimenſions of a wheel for a 24 pounder's carriage. Theſe general dimenſions are very uſeful in ſeveral reſpects: ſuppoſe it were required to make wheels for any other calibers than thoſe above, then you muſt either refer thereto, or elſe perform the work by gueſs. Again, theſe dimenſions being expreſſed by the ſame parts as the guns, they may both be conſtructed upon the ſame ſcale; which cannot be done in the common manner without a great deal of labour and difficulty: in ſhort, artillery would be incomplete without them; becauſe it is not ſufficient to know how to execute what has been done before, but any other work of the ſame kind that may be neceſſary.

The *Span*, or interval between the wheels, varies in different countries; even every county in *England* obſerves a different width, which is very inconvenient for thoſe who travel in carriages. The artillery carriages are made like thoſe in *Flanders*, which is four feet eight inches; but as the fellies are not of the ſame breadth in all wheels, we ſhall make the diſtance between the middle of the fellies five feet in all the carriages uſed by land, which are hereafter mentioned, the truck one excepted.

Iron-work of an axle-tree. Plate IX.

a. Axle-tree bar		——	——	1
b. Clouts	body	——	——	2
	linch	——	——	2
c. Axle-tree hoops	linch	——	——	2
	arms	——	——	2
	body	——	——	2
d. Hurters with ſtraps		——	——	2
f. Waſhers		——	——	2

g. Linch

g. Linch pins	——	——	2
h. Axle-tree bolt	——	——	1
k. Single forelock	——	——	2
Clout nails	——	——	12
Dog nails	——	——	8

Tools neceſſary to prove and load guns.

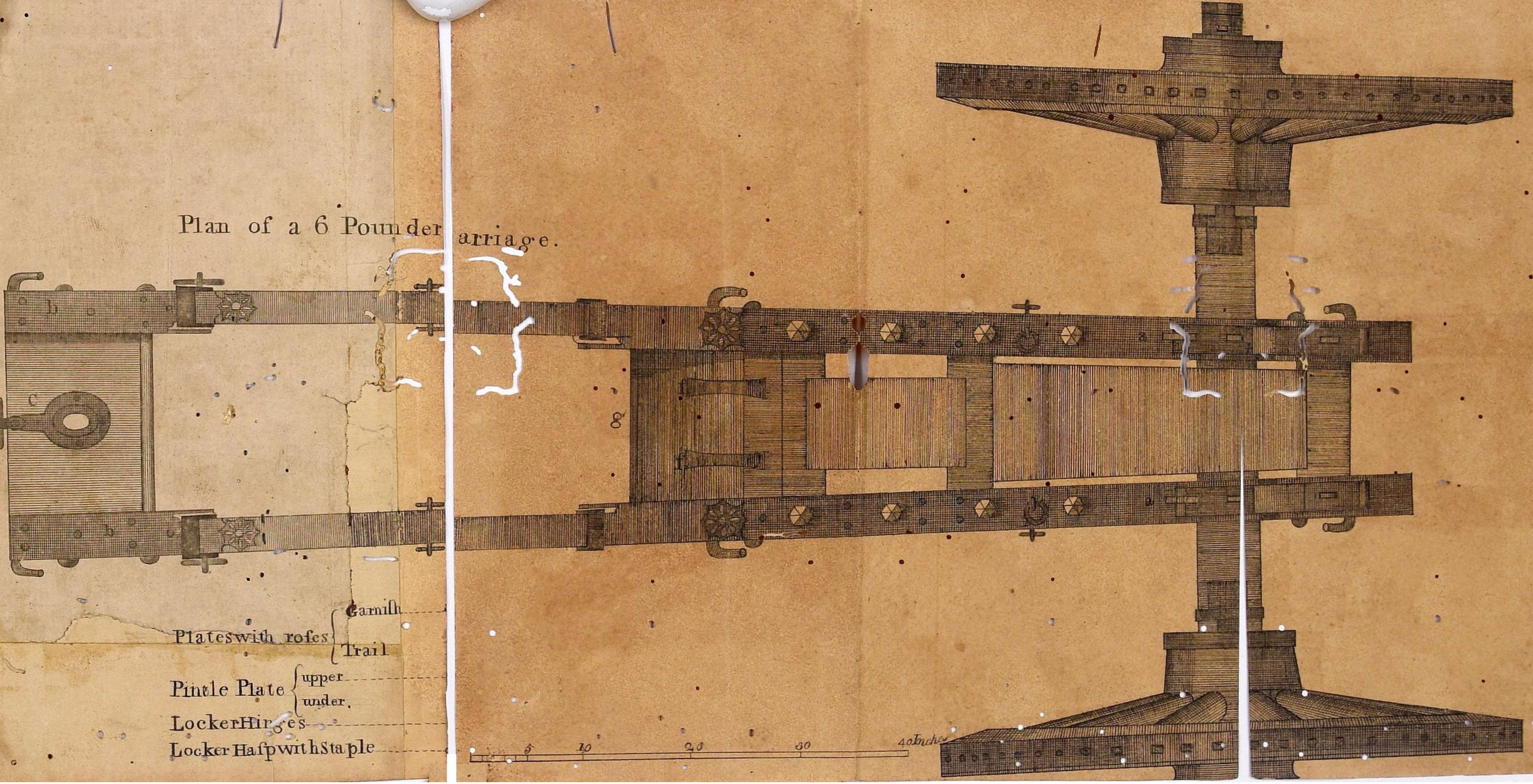
The ſearcher is an iron ſocket with branches, from four to eight in number, a little bent outwards, with ſmall points at their ends: to this ſocket is fixed a wooden handle, from 8 to 12 feet long, of about an inch and a quarter diameter. This ſearcher is introduced into the gun after it has been fired, and turned round, to diſcover the cavities within; and after their diſtances are marked on the outſide with chalk, they make uſe of another ſearcher, that has only one point, about which a mixture of wax and tallow is put to take the impreſſion of the holes; and if there are any of a quarter of an inch deep, or of any conſiderable length, the gun is rejected as unſerviceable to the government; though the iron is ſold to merchants. The gun is thus proved and ſearched twice.

The reliever is an iron ring fixed to a handle by means of a ſocket, ſo as to be at right angles: it ſerves to diſengage the firſt ſearcher, when any of its points are retained in a hole, and cannot otherwiſe be got out.

The worm is a double-wired ſcrew, fixed to a handle by means of a ſocket; it ſerves to draw out the wadding or bottoms of cartridges which remain in the gun after frequent firing, and which would otherwiſe accumulate ſo much, that other cartridges could not be rammed home enough to reach the priming, whereby the gun would miſs fire.

The ladle is made of copper, about three diameters of the ſhot long, and the thickneſs equal to the windage of the gun: it is of a cylindric form, having an opening above of about a ſixth part of the circle, and made

Plan of a 6 Pounder Carriage.



like a ſcoop at the end. The uſe of the ladle is to introduce the charge of powder into the gun, when it is not made up into a cartridge, or to looſen the ſhot, and draw it, in caſe it is retained by duſt got into the gun after much travelling.

The rammer is a cylinder of wood, whoſe diameter and length are each equal to the diameter of the ſhot, with a handle fixed to it; it ſerves to ram home the ſhot and powder when the gun is loaded.

The ſponge is likewiſe a cylinder of wood, from 10 to 12 inches long, of the ſame diameter with the rammer, and covered with lambſkin, ſo as to fit the gun exactly; it is commonly fixed to the other end of the rammer's handle, in ſmall guns, but has a ſeparate one in thoſe of larger calibers. The uſe of the ſponge is to clean the piece before and after it is [illegible]. The [illegible]th plate repreſents the forms of theſe tools, whereby the reader may have a clear conception of them.

Guns are proved various ways, to find whether they are ſufficiently ſtrong; the moſt common in *England* is with a charge of powder, which weighs as much as the ſhot in all pieces under a 24 pounder; which, if braſs, is loaded with 21 pounds, the 32 pounder with 26 and 12 ounces, the 42 pounders with 3[illegible] pounds 8 ounces*; but in *France* they are charged with two thirds of the ſhot's weight only. Sometimes water is forced into them, but this proof is inſufficient; it has been found, that though the water penetrated through the piece in ſeveral places, yet they were very good and ſerviceable. The beſt and ſureſt way of proving pieces made after a new pattern, or of ſome new metal, is to charge them with no more powder than they are loaded with in action, and to fire them 2 or 300 rounds as quick as poſſible; and if they ſtand this trial, there is no danger of their

* The charge of the iron 24 pounder is 18 pounds; that of the 32 is 21 pounds 8 ounces; and the 42 is 25 pounds. As to the light braſs field pieces, they are proved with half the weight of the ſhot; except the 24 pounder only, with 10 pounds.

burſting

burſting afterwards. This has been done by our light 6 pounders, when they were firſt introduced into our ſervice. Mr. *De Valliers*, lieutenant-general of the artillery in *France*, has propoſed another method for proving pieces, which is, inſtead of loading them with ſhot, to ram clay in as hard as poſſible two feet deep. But I doubt whether an iron cannon could ſtand ſuch a proof, nor would I adviſe the trial.

To conſtruct field carriages. Plate X.

As field pieces are ſhorter and much lighter than thoſe above, their carriages likewiſe obſerve the ſame proportion. They have the ſame form, but their wheels are only four feet two inches high; which, in my opinion, is too low; for the draught of low wheel carriages is known to be greater than the higher: and, though the guns are lighter, yet that is no reaſon to make the draught greater. I think, if they were 4.5 feet high, it would be much better; but it being no eaſy matter to change any thing eſtabliſhed by cuſtom, we ſhall inſert the dimenſions uſed at preſent, that the reader may ſee what has hitherto been the practice, leaving my obſervations to his judgment, either to approve or not, as he pleaſes.

Dimenſions of field carriages.

Calibers	24	12	6	Parts
Length of the plank	108	106	94	13 : 4
Height of the plank	15.6	14	12.4	3 : 6
Thickn. of the plank	4.5	3.7	3	0 : 18
Cheeks, height before	14.5	12.7	11	2 : 18
Height at the center	12	10.9	9.8	2 : 16
Height at the trail	10	9.2	8.4	1 : 16
Length of the trail	11	10.5	10	1 : 22
From head to center	10	45	40	11 : 6
Width within before	11.5	10.7	10	2 : 1
Width within behind	17	15	13	2 : 15

Dimenſions

Dimensions of the wheels.

Caliber		24	12	6	Parts
Wheel, height		50	50	50	
Nave, length		15	13	12.7	3 : 0
Diameter	body	13	11	10.6	2 : 10
	middle	14	12	11.6	2 : 15
	linch	12	11	10	2 : 5
Fellows	height	4.7	4	3.6	1 : 0
	breadth	3.3	2.8	2.4	0 : 16
Spokes	breadth	2	1.8	1.7	0 : 9
	thickneſs	3.5	3.2	2.9	0 : 17

Of the axle-tree.

Caliber		24	12	6
Axle-tree, length		68	72	76
Body	length	39	40	42
	breadth	6	5.5	5
	height	8	7	6
Arms, length		18	16	15.7
Diameters	body	6	5.5	5
	linch	4	3	3.5

Theſe dimenſions are in inches and decimal parts, except thoſe general ones in the fourth column, which repreſent diameters of the ſhot and parts, the whole diameter being divided into 24, as in the conſtruction of guns. The length of the planks are here 13 diameters of the ſhot and four feet. The width within of theſe carriages may be more or leſs, as the thickneſs of metal is varied.

The conſtruction of travelling carriages given before, ſerves likewiſe for theſe, by making uſe of the laſt dimenſions inſtead of the former; the only difference is, that there is no bed tranſom here, becauſe ſcrews are

I uſed

uſed to raiſe theſe light pieces inſtead of wedges; for which reaſon the center tranſom is two diameters broad, and but one thick; it is placed in the middle of the height of the cheeks at the center, ſo that the neck of the caſcable anſwers to the middle of the breadth of the tranſom, the ſcrew being fixed there.

It muſt be obſerved, that on each ſide of theſe carriages is a locker or box of two feet long, its upper ſurface even with, or about an inch above the upper part of the axle-tree, extending from thence towards the trail; and its depth is equal to the height of the axle-tree. Theſe lockers ſerve to hold ſhot upon a march, and are covered each by another box that ſlides on, and is faſtened with a bolt, in which cartridges are lodged, to be ready for firing at any time, without having recourſe to the ammunition carts.

The iron work of theſe carriages is nearly the ſame as in the former, only not ſo ſtrong; and there is but one garniſh bolt, which ſupports the fore part of the locker and no garniſh nail, though there are three marked by miſtake in the XIth plate. The eye bolt next to the joint bolt paſſes through the axle-tree band behind, and not before as in other carriages; the the fore part of the band is only faſtened by the fore eye bolt. We have marked but one tranſom bolt at the center and one at the trail, though they make two at preſent in each of theſe places, which is ſuperfluous; the *Saxon*, who brought theſe pieces into uſe here, made no more. The draught hooks are placed to the breaſt tranſom plates, inſtead of fixing them to the axle-tree, as practiſed; becauſe the horſes draw with more ſtrength when the hooks are nearly breaſt high. Laſtly, inſtead of making hooks to the trail tranſom plates, there are ſubſtituted nails about four inches long, which we imagine are much more convenient than the former. The waſhers have alſo hooks, to which are faſtened the ropes by which the gunners draw the gun along.

There